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A FURTHER STUDY OF THE EFFECT OF PRESSURE ON THE WAVE-LENGTHS OF LINES IN THE ARC SPECTRA OF CERTAIN ELEMENTS.

By W. J. HUMPHREYS.

IT has been shown[1] by Mohler and myself that, with the possible exception of the lines of the carbon bands, the wave-lengths of the lines in the arc-spectra of the twenty-three elements we examined increase with increase of pressure about the arc, that this increase is very different for different elements, and that it is always proportional, for any given element, to the wave-length and to the increase in pressure. It was also shown that the increase in wave-length, shift as we called it, is approximately proportional to the product of the coefficient of linear expansion of the substance in the solid state and the cube root of the atomic volume, that it is inversely proportional to the absolute melting points of the elements in question, and finally, that in most cases the cube roots of the atomic weights of the elements of a Mendelejeff group are proportional to the shifts of their lines.

In view of these facts it seemed desirable to examine the effect of pressure on the wave-lengths of the lines of other ele-

[1] *Ap. J.*, February 1896.

ments. This was done, and the results are given in the following tables. The method of obtaining the photographs of the spectra, and of measuring them, was the same in this as in the former investigation. As before, the pressure about the arc was obtained by pumping air into a closed cylindrical vessel provided with a quartz window and suitably constructed stuffing boxes for the carbons. (This apparatus was devised and constructed several years ago by Professor Rowland for the purpose of sometime investigating the effect of pressure on arc-spectra.) About one hundred and seventy-five negatives were obtained, and the best of them carefully measured. The results of the measurements are given in Table I., in which the upper numbers in the line of each wave-length are the observed shifts in thousandths of an Ångström unit and the lower their values for wave-length 4000. As far as possible the wave-lengths are taken from Professor Rowland's table of solar wave-lengths, in process of publication in the ASTROPHYSICAL JOURNAL, and from a former table of his published in *Astronomy and Astrophysics*;[1] a few are taken from other sources, but it was necessary to determine many of them by comparison with known lines in their neighborhood. As exact wave-lengths are not aimed at, only such approximation is given as will serve to surely identify the line in question.

It will be noticed that just as the calcium lines H and K, as shown in the former paper, each shift half as much as the calcium line near G, so too, approximately, the same thing holds for the three analogous lines of strontium and of barium. This made it necessary to divide the strontium and the barium lines each into two groups, marked A and B, as was done in the case of calcium.

It has been suggested by Schuster[2] that the shift is probably due to the "proximity of molecules vibrating in equal periods." The suggestions of so eminent an authority should always receive most careful attention, but that the shifts of the spectral lines under the given conditions, are due to the cause mentioned seems

[1] *A. and A.*, 12, 1893. [2] *Ap. J.*, April 1896.

impossible, since they are practically independent of the amount of material in the arc; a fact well established before the publication of Schuster's suggestion, and established, too, by the very process he proposed, that is, by varying between wide limits the quantity of material in the arc. The substance that showed this quite as well if not better than any other was titanium. The carbons used contained traces of a dozen or more impurities, of which titanium was one. This gave a few very fine but quite measurable lines whose width was practically the same under different pressures. Photographs of titanium spectra were taken with increasing amounts of material in the arc till the quantity was made as great as possible, but the shifts of the lines remained practically the same for the same pressures. The effect of quantity of material on the shifts of most lines at least, if it have any value at all, is certainly of the second order in comparison with that of pressure.

Since the coefficient of linear expansion is known for only about half a dozen of the elements given in Table I., it is impossible to make many tests of the relation between shift and the product of linear expansion by the cube root of the atomic volume. In one case, that of antimony, by taking the expansion along the axis of the crystal, the agreement is fairly close, but the results for arsenic, mercury, potassium, and rubidium are very far wrong. It should be stated, however, that the coefficients of expansion have been taken at 40° C., and that as mercury is a liquid at this temperature while the other elements examined are solids, an exact comparison between them cannot be made. Besides, as the coefficients of expansion depend upon temperature, no exact comparison can be made between the properties of the metals and their coefficients of expansion if these are taken at the same temperature. Possibly the coefficients of expansion should be taken at a fixed distance from the melting points. At any rate the greatest want of agreement is given by those metals which, like mercury, potassium, and rubidium, have the lowest melting points.

The reciprocals of the absolute melting points continue to

be, in most cases, quite approximately proportional to the shifts of the lines of the respective elements. This is shown in Table II., in which S is the shift in thousandths of an Ångström unit for wave-length 4000 and a pressure of twelve atmospheres. T is approximately the absolute melting point, as given in Nernst's *Theoretical Chemistry*. $\frac{48600}{T}$ gives the quotient indicated. This number is the same that was used in the article by Mohler and myself, already referred to, and was taken to make the observed and calculated shifts of the iron lines agree.

The large number of elements that have been examined, forty-six in all, makes necessary a modification of the statement concerning the connection between their atomic weights and the shifts of their lines. The connection is this: The shifts of the spectral lines of the elements in either half (right or left half as commonly tabulated) of a Mendelejeff group are proportional to the cube roots of the atomic weights of the elements that produce them. This is shown in Table III., each horizontal row of which shows the comparison between the observed shifts of the lines of one element, and that calculated for them from the observed shifts of the lines of another element of the same half of a Mendelejeff group. The lines of a few elements shift just half the calculated amount, and the agreement in these cases between half the calculated values and the observed is shown in Table IV.

Two metals, neodidymium and uranium, do not fit in either table. The observed shift of the neodidymium lines for twelve atmospheres and wave-length 4000 is 11, the calculated for didymium 35; the observed for uranium 9, and the calculated 43. The peculiar behavior of didymium in other respects, and the fact that it is one of the least understood of the elements, makes its behavior in the present instance of but little surprise. Not so much can be said of uranium, though it, too, is not free from peculiarities and besides its atomic weight is the highest known. The want of agreement between the calculated and observed shifts is true not only of these elements but also of carbon and boron, but in these two cases agreement could not be expected,

partly because they are non-metallic while the others are metallic elements, but especially because they both belong to the first Mendelejeff series, the elements of which are in general not comparable in other respects with those of the following series. In the relation between the shifts of their lines and their atomic weights, as in other respects, it is only the elements of the series after the first that are comparable with each other. The agreement, as tabulated for beryllium, though a metal, must therefore be regarded as probably accidental.

The photographs of a few elements, arsenic, gold, antimony and especially sodium were not very good, and so it may happen that future measurements will cause some change in the values of their observed shifts.

What the above facts all mean — how to interpret them — does not appear very evident, and I have only one suggestion to make, which is, that the atoms of either half of any Mendelejeff group differ in weight because and only because they differ in size, that is, that they have the same density. If this be true and if, as seems most probable, the atoms have the same general shape, then the cube roots of their weights are to each other as their linear dimensions, and hence the shifts of the lines would be to each other as the linear dimensions of the atoms that produce them, which in turn is in perfect accord with the known facts, first — that the change in the linear dimensions of a body, due to pressure or to temperature, is proportional to its linear dimensions, and second, that the time of the elastic vibration of a body as well as that of its electric oscillation increases with increase of its linear dimensions.

On this supposition the fact that the lines of certain elements shift only half the calculated amount may be explained by assuming their atoms to dissociate in such manner that the linear dimensions of the parts are only half that of the original whole.

In closing I wish the pleasure of thanking Professor Rowland and Dr. Ames, Directors of the Physical Laboratory, for their constant interest and frequent assistance during the entire time of this investigation.

TABLE I.

Element	Pressure in Atmospheres	6	6½	6¾	7	7½	8	8½	9	9½	10	10½	11	11½	12
				21											
Sb	3267.6			26											
								20	18						
As	2898.83							28	25						
					45										
Ba	4432.13				41										
					36								56		
"	4506.11				32								50		
							52				56	58			
"	5535.69						38				40	42			
	Average for				41		52				56	58	56		
"	group A				37		38				40	42	50		
					23			24			32	34	40		
"	4554.211				20			21			28	30	35		
											34				
"	4934.237										28				
	Average for				23			24			33	34	40		
"	group B				20			21			28	30	35		
						11									
Be	3130.6					14									
						19									
"	3321.3					24									
						19									
"	3321.5					24									
	Average for					16									
"	beryllium					21									
		138			123										
Cs	4555.45	121			108										
		95			78										
"	4593.34	82			68										
	Average for	117			101										
"	caesium	102			88										
			20												
Ce	3895.224		21												
			14												
"	3896.917		14												
			22												
"	3898.4		23												
			17												
"	3912.5		17												
			13												
"	3917.7		13												
			8												
"	3918.4		8												
			20												
"	3919.9		20												
			22												
"	3921.6		22												
			17												
"	3929.3		17												
			17												
"	3931.2		17												

TABLE I.—*Continued.*

Element	Pressure in Atmospheres	6	6½	6¾	7	7½	8	8½	9	9½	10	10½	11	11½	12
			19												
Ce	3940.4		19												
			8												
"	3941.1		8												
							8								
"	3949.2						8								
			8												
"	3953.7		8												
			10												
"	3955.4		10												
							15								
"	3957.4						15								
			7												
"	3961.0		7												
			6												
"	3964.6		6												
			12												
"	3971.8		12												
			17												
"	3972.2		17												
			19												
"	3975.1		19												
			7												
"	3978.7		7												
			12												
"	3984.7		12												
			11												
"	3989.5		11												
			15												
"	3992.5		15												
			17												
"	3993.0		17												
	Average for		14												
"	cerium		14												
									18						
Ndi	4279.874								17						
									7						
"	4281.0								7						
									6						
"	4284.8								6						
									7						
"	4302.7								7						
									12						
"	4319.1								11						
									3						
"	4328.1								3						
									4						
"	4329.2								4						
									5						
"	4334.3								5						
									11						
"	4348.0								10						

TABLE I.—*Continued.*

Element	Pressure in Atmospheres	6	6½	6¾	7	7½	8	8½	9	9½	10	10½	11	11½	12
									5						
Ndi	4362.2								5						
"	4385.8								15						
"	4401.0								14						
"	4420.7								13						
"	4421.3								6						
"	4424.5								5						
"	4434 0								14						
"	4434.5								13						
"	4444.4								8						
"	4446.5								7						
"	4458.7								10						
"	4467.5								9						
"	Average for neodidymium								13						
									12						
									2						
Au	4041.07				20				2						
"	4065.22				20				2						
"	Average for gold				34				4						
					33				4						
					27				6						
					26				5						
									8						
La	3921.695								8						
"	3929.363						13		21						
"	3949.199						13		21						
"	3995.899						26		32						
"	4031.865						26		33						
"	4043.054						21		24						
"	4077.498						21		24						
"	4086.861						7		35						
"	Average for lanthanum						7		35						
							29		14						
							29		14						
							17								
							17								
							21								
							21								
							19		25						
							19		25						
											16		21		
Mg	2852.239										22		29		

TABLE I.—*Continued.*

Element	Pressure in Atmospheres	6	6½	6¾	7	7½	8	8½	9	9½	10	10½	11	11½	12
									33		28				
Mg	3829.501								34		29				
									30		31				
"	3832.450								31		32				
									40		30				
"	3838.435								41		31				
									66						
"	5167.497								51						
									62						
"	5172.856								48						
									47						
"	5183.791								36						
	Average for								46		26		21		
"	magnesium								40		29		29		
											63		63		
Hg	3650.3										70		70		
											90				
"	5461.0										66				
	Average for										77		63		
"	mercury										68		70		
														31	
Mo	3132.749													40	
														27	
"	3158.3													34	
									28					32	
"	3170.5								33					40	
									18					33	
"	3194.2								22					41	
	Average for								23					31	
"	molybdenum								28					39	
										27					
Nb	3914.8									28					
										13					
"	3937.7									13					
								22		24					
"	4059.0							22		24					
								30		32					
"	4079.9							29		31					
	Average for							26		24					
"	niobium							26		24					
							76	88							
K	4044.294						75	87							
							88	96							
"	4047.338						87	95							
	Average for						82	92							
"	potassium						81	91							
							73	123							
Rb	4201.98						70	117							
							75	88							
"	4215.72						71	84							
	Average for						74	106							
"	rubidium						71	101							

TABLE I.—*Continued.*

Element	Pressure in Atmospheres	6	6½	6¾	7	7½	8	8½	9	9½	10	10½	11	11½	12
									21		25		31		
Si	2881.695								29		35		40		
"	3905.660									31			44	40	39
"	Average for silicon									32			45	40	40
									21	31	25		38	40	39
									29	32	35		43	41	40
Na	3302.504					13									
						16									
													26	39	
Sr	4077.885												26	38	
"	4215.703											34	34	45	
"	Average for group A											32	32	43	
												34	30	42	
												32	29	41	
"	4607.510				53			51			57		53		
					46			44			50		46		
								17							
Ti	3900.681							17							
								15							
"	3904.926							15							
								15							
"	3913.609							15							
								13							
"	3924.673							13							
								9							
"	3930.022							9							
								10							
"	3947.918							10							
								9							
"	3948.818							9							
								11						18	
"	3956.476							11						18	
									14					21	
"	3958.355								14					21	
								18							
"	3962.995							18							
								9							
"	3964.416							9							
									15					16	
"	3989.912								15					16	
													15	22	
"	3998.790												15	22	
								13							
"	4009.079							13							
								15							
"	4024.726							15							
	Average for titanium							13	15				15	19	
"								13	15				15	19	
										20			13		
W	4009.0									20			13		
													15		
"	4074.7												15		

TABLE I.—*Continued.*

Element	Pressure in Atmospheres	6	6½	6¾	7	7¾	8	8½	9	9½	10	10½	11	11½	12
	Average for									20			14		
W	tungsten									20			14		
															12
U	3886.4														12
"	3993.6									4			3		
										4			3		
													5		
"	3912.7												5		
													4		
"	3916.0												4		
										7			11		14
"	3932.2									7			11		14
													7		
"	3951.5												7		
													6		
"	3954.9												6		
													4		
"	3982.6												4		
													5		
"	3986.0												5		
													13		
"	3987.6												13		
													12		
"	3989.7												12		
													10		
"	4050.3												10		
													13		
"	4064.6												13		
										4					
"	4090.4									4					
	Average for									5			8		13
"	uranium									5			8		13
							5								
V	3902.399						5								
							9				13				
"	3910.984						9				13				
							14				17				
"	3913.0						14				17				
											23				
"	3914.5										24				
							13								
"	3922.560						13								
							22								
"	3924.8						22								
							12				18				
"	3925.4						12				18				
							14								
"	3928.1						14								
							5								
"	3934.2						5								
							18				19				
"	3937.7						18				19				

TABLE I.—*Continued.*

Element	Pressure in Atmospheres	6	6½	6¾	7	7½	8	8½	9	9½	10	10½	11	11½	12
											20				
V	3938.3										20				
"	3939.5						26				23				
"	3950.4						26				23				
"	3979.6						17				15				
"	3984.5						17				17				
"	3984.7						16				15				
"	3989.0						16				15				
"	3990.712						21				24				
"	3992.971						21				24				
"	3998.9						12				22				
"	4042.8						12				22				
"	4051.204						22								
"	4051.491						22								
"	4057.2						15								
"	4092.821						15								
"	4105.318						14								
"	4120.6						14								
"	4123.539						17								
"	4128.251						17								
"	4132.100						16								
"	4134.589						16								
"	Average for vanadium						21								
							16				19				
							16				19				
									13						
Zr	3958.355								13						
"	3999.117								24						
"	4029.796								24						
"	Average for zirconium								23						
									23						
									20						
									20						

TABLE II.

Element	S	T	$\frac{48600}{T}$
Sb	49	710	68
Ba	58 34	748	65
Be	36	>1270	< 39
Cs	161	300	162
Au	49	1310	37
Mg	46	1023	47
Hg	81	233	209
K	130	335	145
Rb	130	311	156
Na	25	369	132
Sr	65 37	>748	< 65

TABLE III.

Showing shifts in thousandths of an Ångström unit for twelve atmospheres and wave-length 4000.

Standard.		Calculated		Observed
Cs	161	Rb	139	130
Cs	161	K	109	130
Cu	33	Ag	39	39
Cu	33	Au	48	49
Cu	33	Na	24	25
Ca	54 27	Sr	70 35	65 37
Ca	54 27	Ba	81 40	58 34
Ca	54	Be	33	36
Zu	57	Cd	68	80
Zu	57	Hg	83	81
Zu	57	Mg	41	46
Al	55	In	89	88
Ti	19	Zr	23	28
Ti	19	Ce	27	27
Su	55	Pb	66	60
Su	55	Si	34	43
Bi	49	As	35	38
Bi	49	Sb	41	49
V	25	Nb	28	34
Cr	26	Mo	32	40
Co	24	Rh	29	30
Ni	28	Pd	34	33

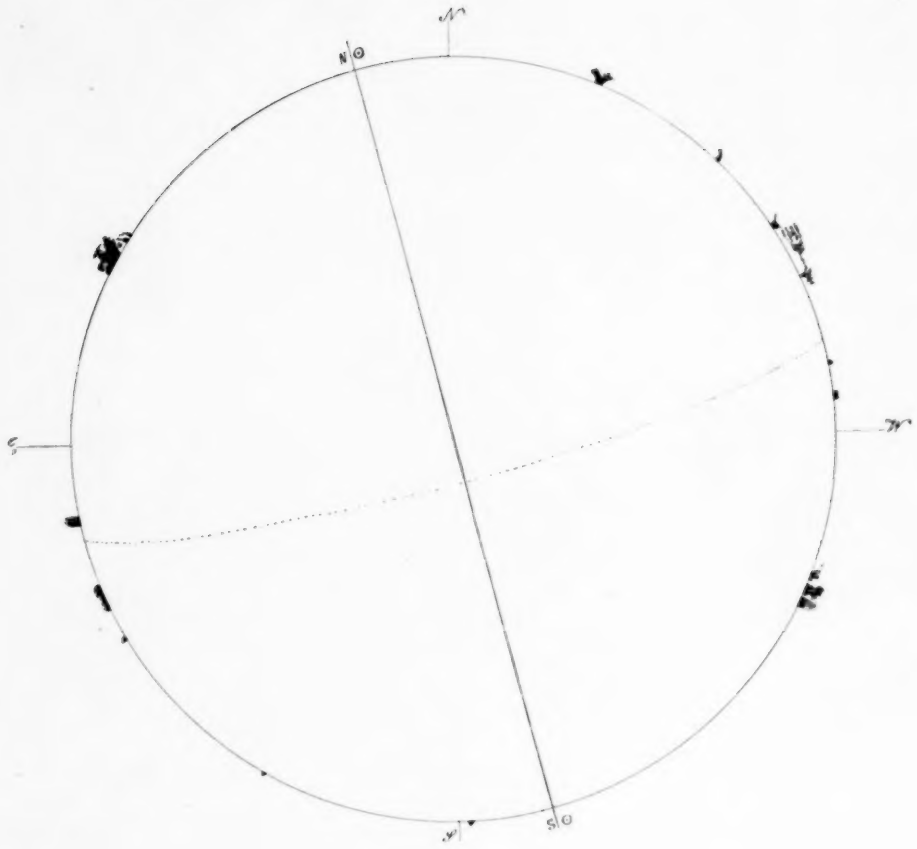
TABLE IV.

Showing shifts in thousandths of an Ångström unit for twelve atmospheres and wave-length 4000.

Standard		Calculated		Observed
La	32	Y	14	15
Al	55	Tl	54	61
Cr	26	W	20	19
Fe	25	Os	19	17
Ni	28	Pt	21	20

JOHNS HOPKINS UNIVERSITY,
October 6, 1896.

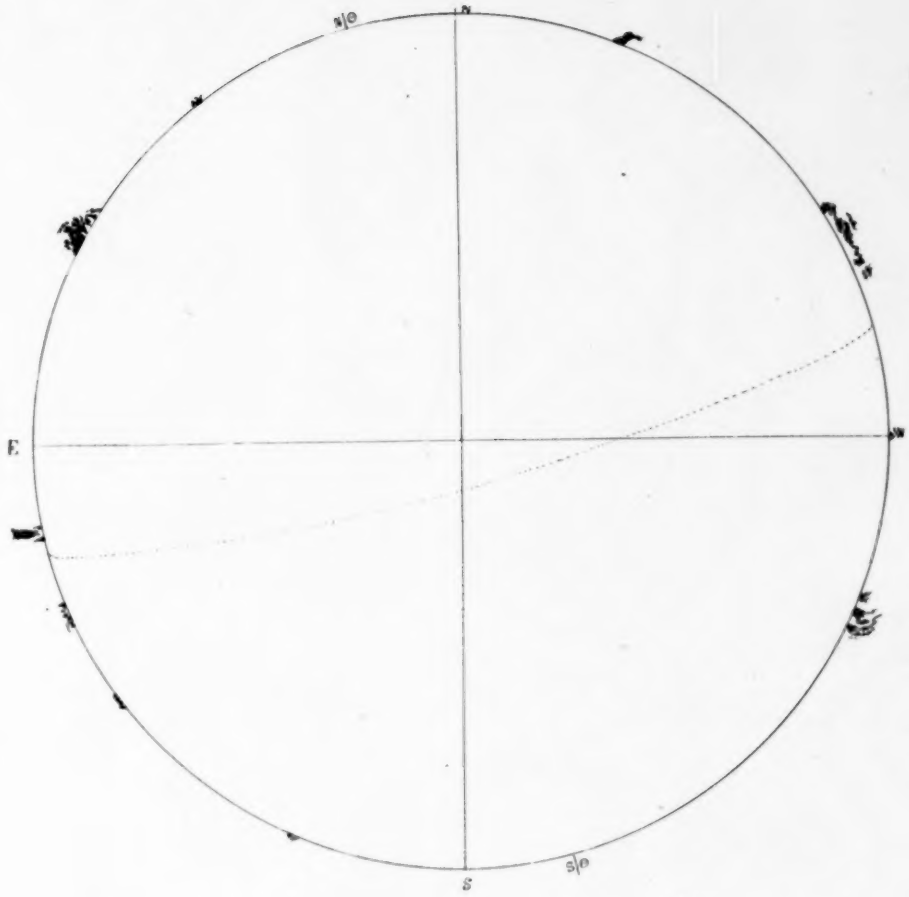
PLATE VIII.



SOLAR PROMINENCES OBSERVED BY J. FÉNYI.

1896, AUGUST 8, $19^h\ 7^m$—$22^h\ 15^m$ G. M. T.

PLATE IX.



SOLAR PROMINENCES OBSERVED BY J. FENYI.

1896, AUGUST 8, $22^h\ 15^m$—$22^h\ 38^m$ G. M. T.

PROMINENCES OBSERVED AUGUST 8, 1896.

By J. FÉNYI.

Soon after the end of the total eclipse the prominences were observed in Kalocsa with a large automatic spectroscope attached to the seven-inch refractor. I have communicated these observations, since they have a special interest in connection with those made during the total eclipse. Greenwich Mean Time was used.

The observations in Kalocsa began about $19^h\ 7^m$, but after 23^m had to be discontinued on account of bad seeing. They were begun again about $22^h\ 40^m$, in spite of the indistinct images, and ended about $22^h\ 15^m$; at the end the image was very good; I accordingly made a second complete survey of the edge of the Sun, but found only small differences in the main features; in fact, only some small changes in elevation. The forms of the prominences, as they were observed the first time, are shown in Plate VIII.

In the following tables only those prominences are recorded which attained a height of more than 30″. The positions were reckoned counter clock-wise from the pole.

FIRST OBSERVATION.

Greenwich Mean Time	Position N. to E.	Heliogr. Long.		Height in Sec. Geocentr.
		E.	W.	
$21^h\ 45^m$	302° 44′ −293° 48′	....	+43	46″
22 8	102 10 −100 20	−26	....	49
	246 14 −243 2	....	−11	43
22 15	63 36 − 56 42	+15	....	50

SECOND OBSERVATION.

$22^h\ 20^m$	302° 16′ −293° 36′	....	+43	42″
	246 24 −243 22	....	−11	42
22 38	102 56 −100 52	−26	....	56
22 15	63 36 − 56 42	+15	....	50

In the accompanying illustrations only the main features of the structure of the prominences can be shown on account of the small scale; but I must remark that, with a fine sky, the spectroscope at my disposal shows the prominences in such detail and sharpness that it is impossible for the delineator to represent truly all that he can see.

If the form, as observed in the spectroscope, differs from that observed at the same time during the total eclipse, the difference cannot be ascribed to the indistinctness of the image, nor to the spectroscope; this difference must be explained on the assumption that the objects though seen contemporaneously are not identical.

HAYNALD OBSERVATORY,
KALOCSA, September 1896.

NOTES ON A METHOD OF DETERMINING THE VALUE OF THE LIGHT RATIO.

By ALEXANDER W. ROBERTS.

WE may define the term magnitude to mean the numerical value which we assign to the apparent brightness of a star whose light is a certain quantitative amount greater or less than that of a fixed standard light.

Thus, let x be the assumed brightness of the standard star selected, then the magnitude of a star K times brighter will be $(x-1)$, and generally

$$L_x \, K^{-n} = L_{(x+n)} \qquad (1)$$

where L_x is the amount of light of the standard star (of magnitude x), and $L_{(x+n)}$ the light of a star whose magnitude is $(x+n)$.

This is the fundamental principle that underlies all photometric determinations of the magnitude of stars; in the first place, and directly, a comparison is secured of the amount of light of the stars whose magnitudes are to be determined, and in the second place, and indirectly, magnitudes are assigned to them by employing some value of K obtained empirically.

But the great majority of the magnitudes of stars from Ptolemy's day down to the present, has been determined without any photometric apparatus. The rapidity and accuracy with which the eye alone can determine slight differences in brightness is made use of to run a gamut of light grades from the brightest star down to the faintest visible speck. The simple expression which, in this case, determines the magnitude of a star in *grades* brighter than the standard star being

$$x - mg. \qquad (2)$$

This is the general principle adopted in eye-estimates of stars, where the quantity measured is the difference in brightness between two stars, expressed in light grades.

These two methods of determining the magnitudes of stars are radically different in principle and in application — facts too often forgotten by those who argue for the special superiority of either. In photometric determinations of magnitude a difference of $5^m.0$ can be as readily determined as a difference of $0^m.5$. And herein lies the excellence of photometric measurements. In eye-estimates a difference of $0^m.5$ can often be measured with an accuracy far exceeding that possible in photometric work, but the probable error increases as the difference to be measured increases. And herein lies the weakness of eye-estimates of the magnitudes of stars. Although these last few sentences do not properly pertain to the purpose of this paper they have an indirect bearing on one portion of it.

Regarding equations (1) and (2), it is evident that they premise the accurate determination of the two constants x and K in equation (1), and x and g in equation (2), before they can be applied to the ascertainment of magnitudes. It is true that theoretically it will not matter what values are given to these constants. In photometric determinations, for example, the standard of reference, say Polaris, may be any arbitrary magnitude, and the "light ratio" K may be any constant, so long as their values remain unchanged all through the series of determinations. The magnitudes resulting from the values of x and K adopted, may, by a simple numerical operation, be related to any other values of x and K. The same holds good for eye-estimates of magnitudes; the reference magnitude x may be arbitrary and the value of a light-step arbitrary also.

Such a mode of procedure, however, would cause needless labor, and no small confusion. What is done in practice is to adopt values for the constants, K and g, that will give results in harmony with the values already determined, either visually or photometrically. When such agreement is secured we have established a relation between the two important constants K and g, or to put it otherwise, we determine the value of the "light ratio."

Hitherto the importance of this determination has been, to a

great extent, dependent on the necessity to which we have referred, of securing some sort of harmony between catalogues of magnitudes obtained photometrically, and the conventional values of Argelander, Gould and Heis.

Of late, however, the advance made, both in the observation and interpretation of the variation of Algol stars, has given an additional importance to the value of the light ratio.

The variation of some stars of the Algol type is of such a nature that it is possible to deduce the orbital elements of the system from an examination of the light curve. This has been done rigorously in the case of the variables Z Herculis and R. S. Sagittarii. The relative size and brightness of the components, as well as the inclination of the system depends largely, however, upon the "light ratio" employed, if the observations have been made by eye-estimates alone. It is true that if the observations along the light curve be taken by the aid of a photometer, so that the actual decrease or increase of light measured is the absolute and final data necessary for an immediate solution of the problem, neither magnitudes nor light ratio enter into the question. And thus it would apparently seem that for the determination of the conditions of orbital movement that produce variation of the Algol type, photometrical observations are much more valuable.

This apparent advantage is somewhat minimized by the fact that observations made by any of the photometers at present used by astronomers must be always, from the nature of things, inferior to estimates by sequences, *when the variation to be measured is of narrow range*. And mainly for this reason, tha by whatever instrument the intensity of the star's light is gauged, the numerical value obtained depends solely on an eye-estimate of the apparent relative brightness of two points of light. Thus, any determination by photometry will be uncertain by at least the constant error that measures the uncertainty of any determination by eye-estimates alone. Then to this error we must add the probable errors arising from unequal polarization, or obscuration, or reflection, as the case may be.

Granting, however, a slight advantage to the method of eye-estimates by sequences, in the matter of accuracy within narrow limits, there is this decided disadvantage that such observations cannot fully be utilized for the determination of orbital movement without the application of the light ratio. If this constant were known with extreme accuracy, the arbitrary magnitudes of any observer could be transposed into absolute light values. When we consider the fact that nine-tenths of the observations of Algol stars have been made without any instrumental aid, other than an ordinary telescope, and further that for many years to come this method of securing observations of variable stars will be more in use than any other, the need for a rigorous determination of the value of the light ratio is evident enough.

The purpose of the present paper is to indicate a simple and expeditious method of determining the value of the light ratio, that, theoretically at least, is much more accurate than that usually adopted, viz., by comparison of different uranometria.

By means of reflection a star is brought into the field of the telescope, and its magnitude is carefully determined from the other stars in the field by the method of sequences. It is of importance that there should be several stars in the field differing from one another in magnitude by only a few grades, and that the magnitude of the reflected star is not brighter or fainter than these stars to be used as comparison stars. The reflected star is then superimposed upon one of the comparison stars and the resulting magnitude is carefully noted.

We thus obtain an equation of the form

$$L_x + L_{x-n} = L_{(x-m)} \qquad (3)$$

x being the magnitude of the fainter of the two stars whose light is combined, $(x-n)$ the magnitude of the other star, and $(x-m)$ the magnitude of the two stars, when combined.

By equation (1)

$$L_x K^{-n} = L_{(x+n)}.$$

Therefore substituting in (3)

$$L_x + L_x K^n = L_x K^m \tag{4}$$

or taking the light of the fainter star as unity,

$$1 + K^n = K^m. \tag{5}$$

Each superposition gives, therefore, a value of the light ratio K; and these can be afterwards weighted and discussed with relation to magnitude.

As far as possible the two stars superimposed should be *nearly* of the same magnitude.

The accuracy of each of the determinations depends entirely on the accuracy with which it is possible to determine the relative magnitudes. I have elsewhere proved the possibility of reducing the average error of a single observation to at least $0^m.04$, when due precautions are taken to eliminate position error.[1] Taking, however, the average error as $0^m.05$, this gives as the theoretical error of a single determination of the value of the light ratio, by this method

$$\pm 0.12.$$

The advantages of this method are:

1. A determination of the light ratio is made simply and solely from a comparison by eye-estimates of the apparent magnitudes of a group of stars. No accessories other than two plane mirrors are required.

2. The light-ratio can be determined with relation to magnitudes. An investigation I made in 1894 and 1895, seemed to point clearly to a varying light ratio (or a varying light grade), but the data on which the determination depends are not sufficient to warrant absolute certainty. *A priori*, however, it would appear that the sensitiveness of the eye cannot be the same for all magnitudes.

3. The determination is made directly for the purpose of determining the light ratio. This is the immediate purpose of the investigation and not a secondary consideration, as is the case when different catalogues are compared.

The importance of an accurate value of the light ratio lies,

[1] See *Ap. J.*, **4**, 184.

as we have said, in its application to the orbital movement of Algol binaries. While investigations dealing with the size and brightness of the components of an Algol system, require an accurate knowledge of the value of the light ratio, if the investigation be based on measures taken by sequences only, it is remarkable that it is to Algol variables that we must look for perhaps the most accurate and simplest determination of this constant.

As yet the variation of known Algol variables can only indicate a limit in one direction to the value of the light ratio, but as the number of stars of this type increases, it is extremely probable that the value will be fixed with considerable accuracy.

Thus, for example, in the case of the southern Algol variable S Velorum, there is a stationary period of about 6½ hours. During this period the star remains constantly at $9^m.25$, and we see only the larger and fainter of the two components. The normal magnitude of S Velorum is $7^m.85$. This is the combined magnitude of both stars; of the large, almost non-luminous central star, and the brighter but smaller satellite. In orbital movement of this nature there must be a secondary but very faint minimum, when the bright satellite comes *in front of* the central star.

Although this minimum can only be barely appreciable, still I think that I have been able to secure reliable observations of it. At this secondary minimum the star seems to be about $0^m.05$ lower than at the normal phase. As the length of the constant phase at primary minimum gives roughly a value of the relative areas of the two spheres, viz.:

18 : 106

we have as the determining equations for the light ratio, L_x being the magnitude of the fainter star and L_{x-y} the magnitude of the brighter but smaller star:

$$L_x \quad - \quad - \quad - \quad = 9^m.25$$
$$\tfrac{88}{106} L_x + L_{x-y} \quad - \quad - \quad = 7 \ .90$$
$$L_x + L_{x-y} \quad - \quad - \quad = 7 \ .85$$

Substituting equation (1) and simplifying,

$$\tfrac{88}{106} L_x + L_x = K^y L_x K^{1.35}$$

$$L_x + L_x K^y = L_x K^{1.40}$$

therefore,

$$K^{1.40} - K^{1.35} = \tfrac{18}{106}$$

and

$$K = 2.57.$$

This star does not afford a very good example of the method of investigation, as the stars are too unequal in brightness, and an error of even $0^m.01$ in the determination of the secondary minimum will modify considerably the value of K obtained. Still the process will be clearly exemplified.

From four other Algol variables we obtain a definite limit in one direction to the light ratio.

The elements of the variable Z Herculis are, according to Dunér,

Mag. at max. $= 6^m.89$

at 1st min. $= 8\ .05$

at 2d min. $= 7\ .35$

Assuming the eclipse to be central,

$$L_{8^m.05} + L_{7^m.35} = L_{6^m.89}$$

and by equation (5)

$$1 + K^{0.70} = K^{1.16}$$

therefore,

$$K = 2.51.$$

This is the maximum limit of the light ratio from Dunér's limits of variation of Z Herculis. If the eclipse is not central then the light-ratio is smaller than that obtained from a solution premising a central eclipse.

In a recent Harvard College Observatory Circular (No. 7), Professor Pickering states that, "the light curve of β Lyrae found by Argelander may be closely represented by assuming that the primary minimum is caused by the eclipse of the brighter body by the fainter, and the secondary minimum by a similar eclipse of the fainter body by the brighter."

The limits of variation of this star have been well determined, and are

$$\begin{aligned} \text{Normal mag.} &= 3^{m}.4 \\ \text{Mag. at 1st min.} &= 4\ .4 \\ \text{Mag. at 2d min.} &= 3\ .9 \end{aligned}$$

therefore,

$$1 + K^{0.5} = K^{1.0}.$$

From which we obtain as the maximum limit of K,

$$K = 2.62.$$

The limits of the southern Algol variable R. S. Sagittarii are,

$$\begin{aligned} \text{Normal magnitude} &= 6^{m}.60 \\ \text{Mag. at 1st min.} &= 7\ .58 \\ \text{Mag. at 2d min.} &= 6\ .89 \end{aligned}$$

There is evidence that the orbit of this interesting system does not lie exactly in the line of sight. Granting that its inclination is zero, we obtain the following equations for the determination of the maximum limit of the light ratio.

$$1 + K^{0.70} = K^{1.01}$$

From which

$$K = 3.24.$$

This value is certainly too great as there is important testimony to the slight inclination of the orbit of R. S. Sagittarii.

The limits of the new southern Algol variable X Carinae, are

$$\begin{aligned} \text{Normal magnitude} &= 7^{m}.90 \\ \text{Mag. at 1st min.} &= 8\ .65 \\ \text{Mag. at 2d min.} &= 8\ .62 \end{aligned}$$

From which

$$1 + K^{0.03} = K^{0.75}$$

and

$$K = 2.57.$$

All the above limits of variation are obtained from eye-estimates, otherwise they could not be utilized for a determination of the

greatest possible value of the light ratio. This greatest possible value, it would seem from an investigation of the limits of variation of the foregoing four stars, cannot be greater than 2.7 or 2.8.

A consideration of the variation of U Cephei and S Velorum, both Algol variable stars of the same type, points to 2.0 as the smallest possible value of the light ratio.

As the number of Algol variables increases the data for more accurate determination of the relation of intensity to apparent magnitude will also increase and we will thus be enabled to secure an independent check upon the value of this important relation obtained by a less circuitous method.

LOVEDALE, July 1896.

THE MODERN SPECTROSCOPE. XX.

ON A NEW FORM OF FLUID PRISM WITHOUT SOLID WALLS AND ITS USE IN AN OBJECTIVE SPECTROSCOPE.

By F. L. O. WADSWORTH.

In a recent article on the Objective Spectroscope[1] by Professor Hale and the writer reference was made to the impracticability of using the ordinary form of glass prism for large apertures on account of the difficulty in securing homogeneous blocks of glass of the required size. The method of overcoming this difficulty suggested in a previous paper[2] is open to the objection (unfortunately a most serious one in most cases) that the expense of making a prism by either of the plans proposed is very considerable on account of the large number of surfaces involved, and the necessity for working the different prisms to the same refracting angle.

Unquestionably the least expensive way of making a very large prism would be to use some suitable liquid in place of glass were it not for the fact that this plan involves the use of two plates of plane parallel glass for the walls of the prism. For some time I have been engaged in an attempt to devise some plan by means of which the glass walls could be done away with, and some cheaper and at the same time efficient construction substituted. Recently a plan has suggested itself which makes it possible to dispense with the containing walls of the prism entirely, and thus not only avoid the main item of expense in its construction, but also get rid of the absorption of the glass or other material used for these parts: a point of great importance in infra-red or ultra-violet work. The plan is such a simple one that it seems hardly possible that it cannot have

[1] *Ap. J.* **3**, 54, June 1896.

[2] "Some New Designs of Combined Grating and Prismatic Spectroscopes of the Fixed-Arm Type and a new Form of Objective Prism," F. L. O. Wadsworth, *Ap. J.* **1**, 245, March 1895.

PLATE X.

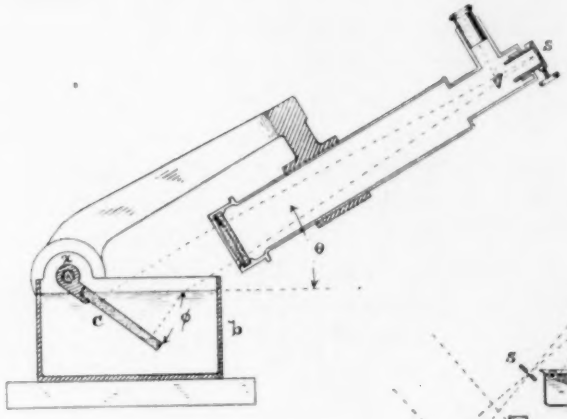


Fig. 1

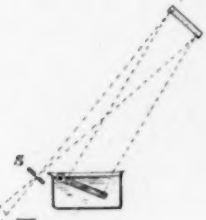
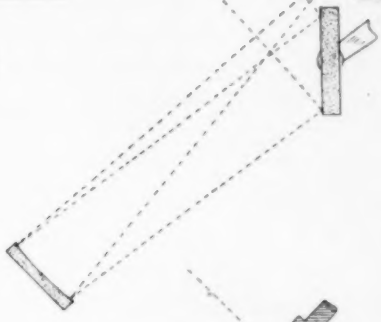


Fig 2



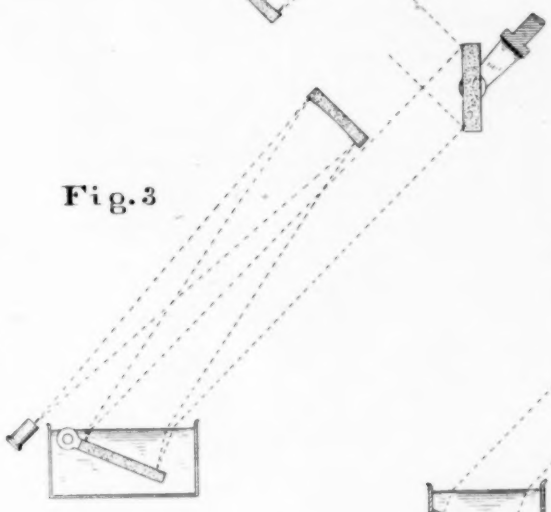


Fig. 3

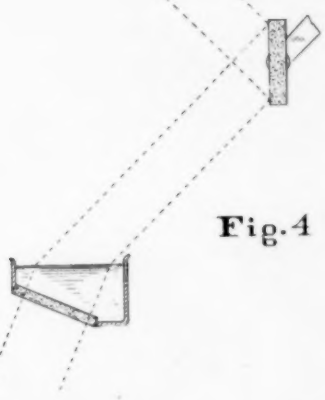


Fig. 4

A NEW FORM OF FLUID PRISM.

suggested itself to others, but as I have not been able to find any description of it published, and as it has on trial proved itself practical and convenient to use, I have thought that a brief description of it might be of interest. The general arrangement is that of a Littrow spectroscope with the axis of rotation of the instrument horizontal instead of vertical as usual. The collimated beam from the slit s (Fig. 1, Plate X.) falls on the free horizontal surface of the liquid contained in a glass or metal cell b and is there refracted. A mirror c, also movable about the axis x of the instrument, is immersed in the liquid at such an angle as to receive the refracted ray normally and reflect it back again to the observing telescope. If θ is the angle between the axis of the telescope and the surface of the liquid and ϕ the angle between the latter and the mirror face (and consequently the angle of the liquid prism), we must evidently have for minimum deviation

$$\theta = \cos^{-1} \mu \sin \phi.$$

It is evident that we may satisfy this condition in either one of two ways: (1) By fixing the axis of the telescope at any particular angle θ and moving the plate about the axis x until the angle ϕ satisfies the above relation; or (2) by fixing the mirror c in position and moving the telescope. The motion of the prism as a whole as in the ordinary spectroscope is of course not here possible.

In the first method we in reality vary the refracting angle of the prism itself. In some respects this is a decided advantage. One unique result is that the resolving power of the instrument is nearly constant for different wave-lengths. For as will be easily seen we have in this case for the resolving power r

$$r = \frac{b}{\tan \theta} \cdot \frac{\frac{d\mu}{d\lambda}}{\mu} = \text{Const.} \frac{\frac{d\mu}{d\lambda}}{\mu}$$

b being the aperture of the telescope. The resolving power therefore depends only on the ratio of $\frac{d\mu}{d\lambda}$ to μ and both of these quantities increase or decrease together.

By varying θ and adjusting as in the first case we can obtain a prism of any equivalent refracting angle desired up to the complement of the angle of total internal reflection for the liquid used.

This form of liquid prism is particularly well adapted for use in an astronomical spectroscope of either the compound or the objective type, in connection with a polar heliostat, provided the latitude of the place is not either too high or too low. In either case the heliostat is arranged to send the beam down the polar axis instead of up it as is usually done. The advantages of this arrangement were pointed out by the writer in the last number of this JOURNAL.[1] In the case of the compound spectroscope the arrangement of parts would be that indicated in Fig. 2 if mirrors were used throughout the train. If lenses were used the whole train would obviously lie in the prolongation of the polar axis.

In the case of the objective spectroscope the arrangement would necessarily have to be slightly modified so as to either use the prism out of the position of minimum deviation as in Fig. 3, (an arrangement similar to that used by Professor Hale in one of his earlier attempts to photograph the corona without an eclipse), or by substituting for the mirror c a plane parallel plate of glass which transmits the beam instead of reflecting it (Fig. 4). The prism then becomes in effect a fluid half prism. The expense of the lower plate would detract from its advantage on the score of first cost, although it would still be less expensive than the ordinary liquid prism with two walls, and very much less expensive than a solid prism of glass of the same size.

It is hardly necessary to remark that in order to secure the best results the whole instrument (or, if the latter be very large, the tank containing the liquid only) must be mounted in such a way as to be unaffected by vibration. This is accomplished by mounting it on a heavy slab of iron or stone supported on rubber[2] blocks, or if this is insufficient by floating it on mercury.[3] In

[1] *Ap. J.*, **4**, 241; see also p. 310 of the present number.

[2] Ordinary cork answers nearly as well if rubber is not available.

[3] Instead of mercury heavy cylinder oil, which was suggested and used by Mr. Hoffman (see *Ap. J.*, **3**, 293) as a substitute for mercury for reflecting surfaces, might be used for this purpose also.

either case it is perhaps well to point out that good results are only attained when the mass supported by the rubber or the mercury is very great; hence the necessity for using large blocks of stone or iron under the instrument itself. The principle involved is of course that no form of support will completely absorb all vibration and that the heavier the mass supported the less will it be affected by the small residue of vibration communicated to it.

KENWOOD OBSERVATORY,
October 1896.

PRELIMINARY TABLE OF SOLAR SPECTRUM WAVE-LENGTHS. XV.

By HENRY A. ROWLAND.

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3133.605	Zr	0	3138.901		0
3133.790		000 N	3139.031		0
3134.080		00 Nd?	3139.221		000
3134.230 s	Ni, Fe	8	3139.279		2
3134.451		1	3139.421		0
3134.510		1	3139.601		00
3134.655		000	3139.781		1
3134.740		00	3139.876		1
3134.830		00	3140.052	Fe?, Co	5
3135.051	V,-	2	3140.131		0000
3135.160		000	3140.324		0
3135.295		000	3140.503	Fe?	2
3135.470	Fe?	1	3140.626		000
3135.567	Fe?	1	3140.872 s	Co,-	3
3135.703		0	3141.053		000 N
3135.821	Fe?	2	3141.221		00
3135.985	Fe?	1	3141.296		0
3136.130		00	3141.411		00
3136.200		000	3141.628	-,Ti?	0
3136.310		0	3141.781	Ti?	00
3136.460		00	3141.916		0000
3136.621	Fe?	2	3142.023		2
3136.705		0	3142.136		000
3136.822	Cr, Co	3	3142.271		000
3137.005		1	3142.339		0
3137.140	Zr	0	3142.585	Fe, Cu?	5
3137.215		000	3142.626		000
3137.445 s	Co	3	3142.791		000
3137.560	Co	000	3142.846	Mn	00
3137.675		00	3143.012	Fe	2
3137.825		00	3143.131		1
3137.880	Co	0	3143.271		00
3138.011		00	3143.357	Fe?	1
3138.129		00	3143.451		0000
3138.191		00	3143.601		2 N
3138.321	Cr?	000	3143.690		1 N
3138.421		0000	3143.879	Ti	4
3138.521		000	3144.011		0
3138.633	Fe?	2	3144.111	Fe	2
3138.798	Zr	1	3144.231		0

PLATE XI.

ERECTING THE POLAR AXIS OF THE YERKES TELESCOPE.

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3144.351		0	3150.947	Co?	0000
3144.441		0	3151.120		1
3144.568		1	3151.212		0000
3144.616	Fe?	1	3151.352		1 N
3144.744		0	3151.467	Fe	2
3144.852	Ti?	1	3151.632		0000
3144.931		000	3151.757		000
3145.040		0	3151.978	Fe?	1
3145.206	Co, Fe	3	3152.115		1
3145.251		2	3152.232		0
3145.484		3	3152.377	Ti,-	5
3145.641		0	3152.572		00
3145.840	Ni,-	2	3152.712		0000
3145.906		1	3152.852	Co,-	1 Nd?
3146.091	Zr	1	3152.972	Cr?	000
3146.221		000	3153.072		0
3146.371		1	3153.173		00
3146 416		0	3153.306	Fe	3
3146.581		0	3153.434	Fe?	1
3146.713		1	3153.683	Cr,-	00 Nd?
3146.871		0	3153.866 s	Fe?	1
3147.049		1	3153.985		0000
3147.183	Co	2	3154.120		00
3147.350	Cr	3	3154.235		00
3147.382	Ti?, Fe?	2	3154.315	Fe, Ti	3
3147.562		1	3154.535		1
3147.714	Fe?	1	3154.608	-,Fe	1
3147.899	-,Fe?	1	3154.710		0
3148.157	Ti	2	3154.758	-,Co	0
3148.283	Mn	1	3154.903	-,Co	1
3148.422		00	3155.055		000 N
3148.555	Fe, Cr	3	3155.245	-,Cr	1
3148.757		0000 N	3155.405	Fe	1
3148.912		0 N	3155.520		00
3149.015		0	3155.737		0
3149.237		000 N	3155.773	Ti	3
3149.432	Co	1	3155.910	V	0
3149.512		000	3156.020		0
3149.612		00	3156.055		0
3149.757		0000	3156.205		0000
3149.839		0	3156.305		0000
3149.967		2	3156.387	Fe	2
3150.013		1	3156.565	Fe?	1
3150.192		1	3156.680		0
3150.344		0	3156.842		00
3150.422	Fe	1	3156.960		0
3150.532		00	3157.030		0
3150.627		000	3157.145	Fe	2
3150.767	Co?	0000	3157.257	Co, Fe?	1
3150.862		1	3157.408		0

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3157.525	Ti?,-	1	3163.336		0
3157.615		1 N	3163.536		2
3157.748		00	3163.671		0000
3157.865		0	3163.796	Cr	0000
3157.996	Fe	1	3163.881		0
3158.110	Fe?	0	3164.001	Fe	1
3158.163		0	3164.043		1
3158.305		00	3164.181		0
3158.465		0	3164.286	Cr	00
3158.517		1	3164.408	Fe?	1
3158.635		0	3164.531		0
3158.747		0	3164.661		0
3158.897	Co	1	3164.798		1
3159.000 s	Ca	2	3164.946		1
3159.125	Fe?	0	3165.011		000
3159.225		0	3165.117	Fe	1
3159.375		0	3165.196		000
3159.463		0	3165.269		1
3159.550		00	3165.378		0
3159.645		1	3165.532	Zr	00
3159.785	Co	0	3165.624		1
3159.945		00 N	3165.787		000 N
3160.049		0 N	3165.987	Fe	1
3160.196		00	3166.070	-,Zr	2
3160.327	Fe?	2	3166.242		0
3160.461	Fe	1	3166.367	Ti	1
3160.586		0000	3166.447		0
3160.726	Cr?	00	3166.550	Fe	1
3160.761	Fe	2	3166.707		0
3160.915		1	3166.786		1
3161.036		0	3166.879		0
3161.146	Mn	0	3166.977		000
3161.317	Ti	3	3167.097		00
3161.495	Fe	1	3167.289 s	Mn	1
3161.536		0	3167.407		0000
3161.666		00	3167.527		000 N
3161.766	Co	000	3167.707		00 N
3161.887	Ti	3	3167.902		1
3162.014		0	3167.971		3
3162.065	Fe	3	3168.022	Fe?	2
3162.236		0000	3168.157		0000
3162.291		0000	3168.263		2
3162.466	Fe?	1	3168.392		0000
3162.546		00	3168.547		000
3162.683	Ti	4	3168.640	Ti	4
3162.816		000	3168.784		0
3162.916		0	3168.968	Fe	1
3163.036		0000	3169.067	Fe?	1
3163.141		0000	3169.187	Co?	000
3163.208		1	3169.304	Co?,-	0

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3169.478		1	3175.931		0000
3169.539		1	3176.099 s	La?, Fe?	1
3169.727		0	3176.211		0000
3169.864	Co	1	3176.410		1 } d
3169.972		0	3176.462	Fe?	1 }
3170.117		0000	3176.556		00
3170.239		00	3176.711		0000
3170.367		0000	3176.786		0000
3170.455	Fe, Mo	2	3176.946		000
3170.592		00	3177.041		0000
3170.822		1	3177.191	Fe?	00
3170.917		0000	3177.413	Co	2
3171.096		0	3177.633	Fe?	2
3171.252		000	3177.791		1
3171.327		0000	3177.933		00 Nd?
3171.466	Fe	2	3178.132	Fe	2
3171.577		0000	3178.272		1
3171.776	Fe?	1	3178.437		0000
3171.882		00	3178.542		00
3172.047		000	3178.620	Mn, Fe?	1 Nd?
3172.162 } s		3	3178.752	Fe?	0000
3172.198 }	Fe?	4	3178.897		000 d
3172.408		0	3179.077	Fe	0
3172.488		0000	3179.172		00
3172.618		0	3179.277	Cr?,-	000 N
3172.758		000	3179.453	Cr?,Ca	5 d?
3172.833	Ti?	0000	3179.624	Fe	1 N
3172.963		000	3179.782		000 N
3173.108		1	3180.012		0
3173.321		0	3180.077		00
3173.519	Fe?	1	3180.232		00 N
3173.661		00	3180.347	Fe, Co	3
3173.716	Fe?	1	3180.602		0
3173.794	Fe?	1	3180.821	Cr	2
3173.951		000	3180.857	Fe	2
3174.061		000	3180.992		000
3174.166		00	3181.102		000
3174.266	Co?	0	3181.242		0000
3174.332		0	3181.312		0000
3174.491		0	3181.387	-,Ca	3
3174.601		1	3181.531	-,Cr?	0
3174.808		2	3181.642	Fe	1
3174.896		0000	3181.752		00
3175.064	Co	1	3181.856	Ni	0
3175.156	Cd?, Fe	0	3181.975	Fe?	1
3175.276		0000	3182.022	Zr	1
3175.425	Fe?	1	3182.172	-,Fe	1
3175.562	Fe	2	3182.232	Co	00
3175.666		0000	3182.357		0
3175.821		0000	3182.427		0

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3182.582		2	3188.656	-,Fe	6d?
3182.762		0 N	3188.934	Fe	2
3182.918	Zr	0	3189.046		000
3182.961		1	3189.196		0000
3183.101	Fe, Ni?	3	3189.281		0000
3183.235	Fe?	2	3189.429		0
3183.372	Ni?	0	3189.606		00 N
3183.428	Cr?	00	3189.746		0000
3183.533	V	1	3189.876		00
3183.631		000	3189.936	Co	000
3183.692		0	3190.076		000
3183.873		0000 N	3190.154	Fe?	1 } d
3184.075		2	3190.216		1 }
3184.109	V	2	3190.276		000
3184.225	Ti	1	3190.406		000
3184.321		0	3190.516		000
3184.490	-,Ni	2	3190.651		000
3184.553		000	3190.795	V	2
3184.658		00	3190.961	Fe?	2
3184.726	-,Fe?	1	3191.011	Ti	3
3184.873		0000	3191.236	Fe?	0
3185.006	Fe	2	3191.306		00
3185.133		1 N	3191.426	Co	000
3185.203		0000	3191.526		0
3185.333		0000 N	3191.676		0000
3185.438		2	3191.776	Fe	2
3185.499	V	2	3191.911		00
3185.675		00	3192.001		00
3185.785		0	3192.120	Ti	2
3185.915		000 N	3192.151		00
3186.090	Co,-	0	3192.306		00
3186.215		0 Nd?	3192.386	Co?	0
3186.383		00	3192.508	Fe?	0
3186.494	Co	0	3192.646		00
3186.564	Ti	1	3192.729		00
3186.745		0000	3192.836		000
3186.863	Fe	3	3192.936	Fe	2
3186.905		1	3193.029	Fe?	1 N
3187.075		00	3193.166		00
3187.175		0000	3193.346	Co, Fe	3
3187.279		0	3193.413	Fe	2
3187.419		1	3193.661		000 N
3187.667		0 Nd?	3193.846		00 N
3187.824	V	2	3193.928	Fe?	1 N
3188.010		0000	3194.091	Mo	000
3188.145 } s	Cr?	1	3194.206	Cu	0
3188.170 }	Fe?	1	3194.346		00
3188.310		0000	3194.451		0000
3188.446		0	3194.543	Fe	1
3188.487	Co	0	3194.636		00

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3194.698		1	3201.494		000
3194.876		000	3201.624		00
3194.961		0	3201.724	Ti	00
3195.085		00	3201.834		000 N
3195.197		0	3202.004		000
3195.252		00	3202.069		000
3195.342		00	3202.253	Ni	1
3195.517		000 N	3202.369		00
3195.705 s	Ni	2	3202.494	V	0
3195.837	Ti?,-	1	3202.651	Ti, Fe	2
3195.987		0000	3202.779		0
3196.102		0	3202.807		0
3196.218	Fe?	3	3202.934		0
3196.307	Fe?	00	3203.054		0
3196.452		000	3203.144	Co	000
3196.577		000	3203.274		0000 N
3196.682		00	3203.435		1
3196.737		00	3203.552	Ti,-	2
3196.947		0000	3203.624		000
3197.037	Fe	1	3203.724		0000
3197.085	Fe	2	3203.824		0000
3197.222	Cr, Ni	3	3203.944	Ti	1
3197.318		000	3204.092		1
3197.473		0000	3204.225		0000
3197.653	Ti, Fe?	1	3204.396		2 Nd?
3197.708		00	3204.565		00
3197.822		1 N	3204.685		0000
3197.983		0000	3204.805		0000
3198.133	V	0	3204.975	Ti?	0
3198.213	Cr?	000	3205.065		000
3198.388		0	3205.225		00
3198.599		1	3205.335		0
3198 799	-,Co	00 Nd	3205.445		00
3199.014	Fe?	000 N	3205.520	Fe	2
3199.249		0	3205.685	V	00
3199.349		0000	3205.765		000
3199.454	-,Co?	0	3205.895		00
3199.639	Fe	4	3205.950	Ti?	000
3199.774		00	3206.119		1
3199.934		0000 N	3206.225		0000
3200.034 s	Ti	2	3206.350		0
3200.249		00	3206.460	Ti ?	000
3200.407		2 Nd?	3206.605		00
3200.581	Ni, Fe	5 Nd?	3206.645		00
3200.734		000	3206.875	-,Ti?	0 Nd?
3200.903	Fe?	2	3207.055	Mn?,-	1
3201.074		1	3207.193	-,Fe?	1
3201.126		1	3207.290		00
3201.239	Fe?	0000	3207.360		00
3201.374		00	3207.525	V	0

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3207.675		00	3213.677		000
3207.788		1	3213.807		00
3207.823		0	3213.857		0
3208.005	Ti?	000	3214.042		000
3208.101		0	3214.143	Fe	2
3208.206		0	3214.185	Fe, Ni	2
3208.326	Cu	0000	3214.335	-,Ti	1 N
3208.464	V	1	3214.515	Fe	2
3208.586	Fe	1	3214.607		000
3208.707	Cr?,-	1	3214.727		00
3208.801		0	3214.889	Ti,-	3
3208.906		000	3214.977		000
3209.006		00	3215.142		000 N
3209.116	Ti?	0000	3215.292		1
3209.229		00	3215.317		1
3209.297	Cr,-	1	3215.467	Co?	0
3209.411	Fe	1	3215.517		1
3209.546		00	3215.707		000
3209.601		000	3215.757		000
3209.736		000	3215.827		0000
3209.786		000	3215.957		1
3209.876		0000	3216.061	Fe	2
3210.046	-,Ni	1 N	3216.162		000
3210.158		0	3216.327		0
3210.337	Fe, Co	3	3216.472		000 N
3210.564		2	3216.659		0
3210.592	Fe?	1	3216.807		1
3210.751		0	3216.928	-,Ni	0
3210.836		00	3217.040	Mn, Ti?	1 N
3210.948	Fe	2	3217.183	Ti	2
3211.056	Co?,-	000	3217.210		1
3211.176		000	3217.413		000
3211.281		00	3217.505	Fe, Cr	2
3211.321		00	3217.658		0000 N
3211.421	Cr?	000	3217.838		0000
3211.602	Fe?	1	3217.954	Ni	1
3211.746		1	3218.048	Ti	000
3211.796	Fe?	1	3218.188		00
3211.996	Fe?	1	3218.318		0000
3212.117	Fe	2	3218.389 s	Ti	2
3212.277		1	3218.563		000
3212.435		0	3218.728		00
3212.552		00	3218.798	Cr?	00
3212.657		1	3218.978		0000
3212.802		00	3219.098	Co?	000
3213.004	Mn,-	2 N	3219.260		1
3213.247	Ti	1	3219.313	Co, Ti	00
3213.423	Fe	3	3219.483		000 N
3213.517		00	3219.543		0000
3213.587		00	3219.711 s	Fe, Cr	2

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3219.919 s	Fe	3	3226.266	Ti	0
3220.079		0000 N	3226.342		0000
3220.259		0000Nd?	3226.462		0000
3220.426		0	3226.562		00
3220.547		0	3226.657	Cr?	00
3220.664		00	3226.854	Fe?	1 } d
3220.721		00	3226.880	-,Ti	2 } d
3220.889		000	3227.007		00
3220.949		000	3227.123	Ni	1
3221.084		0000 N	3227.175	Fe?	1
3221.249		000	3227.292		0000
3221.388	Ni	1	3227.392	Cr?	0000
3221.499	Ti	00	3227.542		0000
3221.659		000	3227.612		0000
3221.773	-,Ni	2	3227.747		0000
3221.874		0000	3227.877	Fe	2 } d
3222.002		0	3227.925	Fe	2 } d
3222.034	Fe?	1	3228.112		0
3222.201 s	Fe	3	3228.219	Mn	1
3222.374		000 N	3228.370	Fe	1
3222.559		000 N	3228.503		000
3222.699		000 N	3228.618		00
3222.844	Ti?	000 N	3228.735	Ti?	2
3222.970	Ti,-	4	3228.953		0
3223.059		000	3229.016	Fe?	0
3223.214		000	3229.263	Fe	2 } d
3223.378		1	3229.324	Ti, Cr	3 } d
3223.479		00	3229.468		0000
3223.564		00	3229.542	Ti	2
3223.631	Ti	0	3229.704		1
3223.754		000	3229.911	Fe?	0
3223.859		000	3229.999	Tl	0
3223.962		0	3230.106	-,Fe	1
3224.154		0000 N	3230.213		0
3224.368 s	Ti,-	2	3230.323	Fe	1
3224.540		0000	3230.588		0 N
3224.600		0000 N	3230.708		00
3224.750	Co	00	3230.843	Mn,-	1
3224.882	Mn	1	3230.962		00
3225.040		0	3231.123	Fe,-	2
3225.146	Ni	1	3231.193		0000
3225.237		0000	3231.338		0000
3225.382		00	3231.442 s	Ti	2
3225.487		000	3231.588		00
3225.577		00 N	3231.703		0
3225.732	Fe?	0	3231.823	Zr	1
3225.827		000	3231.958		0000
3225.919 s	Fe	3	3232.063		00
3226.024		0	3232.193		0000
3226.143	Mn	0	3232.273		00

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3232.407 s	Ti	2	3239.170	Ti	7
3232.509		0000	3239.435		0
3232.664		0000 N	3239.574	Fe	3
3232.804		000 N	3239.786	Ti	2
3232.914	Ti	00	3239.966		000
3233.055	Ni	2	3240.137		0
3233.171	Fe	1	3240.239		00
3233.284	Ni?	00	3240.381		0000 N
3233.394	Cr?	00 N	3240.522	Mn	1
3233.554		0000 N	3240.616		0000
3233.654		000	3240.726	Mn	0
3233.786		00	3240.826		1
3233.879		00	3240.991		0000
3234.093	Fe	2	3241.081	Cr	000
3234.189	Zr,-	0 N	3241.168	Zr	1
3234.394		000 N	3241.256		0000
3234.469		000 N	3241.366		0000
3234.635	Ti	3	3241.509		0
3234.764	Fe, Ni	3	3241.607		0
3234.894		0000 N	3241.721		0000
3235.049		0	3241.806		00
3235.144		00	3241.936		000 N
3235.304		00	3242.125	Ti,-	8
3235.444		0	3242.226		0000 N
3235.674	Co	0	3242.395		1
3235.701	Fe?	0	3242.531		0000
3235.888	Zr	1	3242.607		0000
3235.913		0	3242.747		00
3236.050		0000	3242.827		00
3236.251	Ti	1	3242.952		000
3236.349	Fe	2	3243.132		1
3236.540		00 N	3243.189	-,Ni	6
3236.703 s	Ti	7 N	3243.332	Cu?	000
3236.905	Mn,-	1	3243.532		1
3237.040		000	3243.682	Ti?, Co	000 N
3237.154	Co	1	3243.883	-,Mn	2
3237.260		000	3243.978	Co	1
3237.350		0	3244.147		0000 N
3237.548		1 N	3244.257	Cr	0
3237.700		000	3244.317	Fe	3
3237.840	Cr	00	3244.472		0 N
3237.967	V	2 Nd?	3244.617		00
3238.155		0	3244.667		00
3238.205	Cr	0	3244.822		00 N
3238.330	Ti	000	3244.987		00
3238.435		00	3245.137		00 N
3238.635	Cr?	00	3245.257		00 N
3238.670		00	3245.397		000 N
3238.885		0	3245.517		1
3239.015		00 N	3245.662	Cr	0

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3245.847		0000	3252.729	Ca	0 N
3245.907		0000	3252.865	Cr	0 N
3246.104 s		4	3253.012	Ti, Fe	5
3246.150 s	Fe	3	3253.090	Mn	4
3246.290		0000	3253.158		000
3246.429		000	3253.274		000
3246.613	Fe	2	3253.391		00 Nd?
3246.803		0000	3253.531		000
3246.889		0000	3253.684		0
3247.096	Co	4	3253.731	Fe	2
3247.311	Co	3	3253.841		0000
3247.420	Fe	1	3253.964	Fe	2 N
3247.525		0	3254.078		2
3247.688 s	Cu	10	3254.180	Mn	1 N
3247.908		0000 N	3254.314	Ti	3
3248.095		000 N	3254.381	Co	4
3248.248	Fe	1 N	3254.497	Fe	4
3248.339	Fe	3	3254.590		2
3248.442		0000	3254.881	V, Fe	5 d?
3248.589	Ni	2	3255.150		000
3248.637	Mn	0 N	3255.283		0000
3248.731		1	3255.413		000
3248.841	Ti	2	3255.617	Mn	1 N
3248.987		0000 N	3255.800		000 N
3249.147		1	3255.937		0000
3249.313	Fe	2 N	3256.021	Fe?	6
3249.497	Ti	2	3256.102		0000
3249.577	Ni	2	3256.264	Mn	3
3249.654		00	3256.382		0000 N
3249.754		00	3256.616		1 N
3249.803		0	3256.830	Fe	2
3249.980		0	3257.081		0000 N
3250.046		000	3257.223		2
3250.136	Co	1	3257.355	Fe	4
3250.270		000 N	3257.481		00
3250.514	Fe, Zr?	3 N	3257.549		2
3250.756	Fe	3 N	3257.721	Fe	4
3250.886	Ni	4	3257.944	Cr	1
3251.060		0000 N	3258.028		0
3251.273	Mn	0 N	3258.141		0
3251.375	Fe	3	3258.221	Co	0
3251.472		1 N	3258.408		0000
3251.659		0000	3258.542	Mn, Co	3
3251.732		000	3258.752		1 N
3251.805		0000	3258.904	Fe	3
3251.977	Ti	3	3259.034		0000 N
3252.057		4 d?	3259.183	Fe	3
3252.245		00	3259.357		0000 N
3252.359		0000 N	3259.494		0000 N
3252.560	Fe	4	3259.567		0000 N

RESEARCHES ON THE ARC SPECTRA OF THE METALS. III. COBALT AND NICKEL. I.[1]

By B. HASSELBERG.

IN my investigations on the spectra of the metals in the electric arc I have taken up cobalt and nickel after having completed the work on chromium and titanium.[2] The simultaneous investigation of these two metals is advisable from the fact that on account of their close relationship and the consequently inevitable presence of the one in the other as an impurity, it might be expected that both spectra would contain a large number of common lines. This supposition has been fully confirmed; but it has at the same time been found that the separation of these lines from one another has given much less difficulty than I had anticipated at the outset. For this reason also, the number of cases in which there is still room for doubt is comparatively small.

Of the older investigations in this field of spectroscopy, so far as regards cobalt, those of Kirchhoff[3] and Huggins[4] must be mentioned. In both cases the induction spark was used to produce the spectrum, and on account of this fact, particularly in the case of Kirchhoff, it was possible to observe only the principal lines. The same thing is true of Kirchhoff's observations of nickel. Since further, as at that time it could not be otherwise, the observations are given on an arbitrary scale, from which a reduction to wave-lengths cannot be accomplished with the necessary accuracy, it has not been thought desirable to include these among the determinations which accompany this paper. In this particular the investigations carried on only a

[1] "Untersuchungen über die Spectra der Metalle im electrischen Flammenbogen III., Cobalt und Nickel." Translated from the *Kongl. Svenska Vetenskaps-Akademiens Handlingar*, **28**, No. 6, Stockholm, 1896.

[2] See this JOURNAL, **4**, 116–134, and 212–233.

[3] *Abh. d. K. Akad. d. W. Berlin*, 1861.

[4] *Phil. Trans.*, 1864, p. 139.

short time later by Thalén[1] appear to much better advantage. It is true that these also relate to but a small number of the principal lines; but on account of the fact that these lines are based directly upon Ångström's system of wave-lengths, it is possible to reduce their wave-lengths to Rowland's system and consequently to make a reliable comparison with the corresponding values in my catalogue. The result of this comparison, as will be seen later, is similar to that which the comparison of our observations of titanium has given, viz., the Thalén determinations possess an accuracy to be found nowhere else in the spectroscopic observations of that period.

These investigations, when taken together with a few of the principal lines observed by Ångström and Thalén[2] in the electric arc and certain isolated observations by Schuster[3] and a few photographic determinations made by Lockyer[4] in the short region between λ 3900 and λ 4000, include all that have hitherto been made in the visible part of both spectra.[5] As for the ultra-violet, Cornu[6] determined the positions of a few of the principal lines of nickel in connection with his investigations on the solar spectrum; a systematic examination of the entire ultra-violet region, both for cobalt and nickel, was first published in 1888 by Liveing and Dewar.[7] In this research the wave-lengths of a considerable number of the principal lines of both spectra were directly determined with the aid of a Rowland plane grating, the constant of which was found from measurements of the deviation of the E line of the solar spectrum in connection with Ångström's wave-length of this line; and the remaining metallic lines were measured with reference to these on photographs taken with

[1] *Nova Acta Upsal.*, III, Ser. 6, 1868.

[2] ÅNGSTRÖM, *Recherches sur le Spectre solaire*, 1868.

[3] WATTS, *Index of Spectra*, 1889.

[4] *Phil. Trans.*, 1881, p. 111.

[5] While this is being written numerous determinations of cobalt and nickel lines are being published by Rowland in his tables of solar spectrum wave-lengths. See the ASTROPHYSICAL JOURNAL for 1895–6.

[6] *Spectre normal du Soleil*, 1881.

[7] *Phil. Trans.*, 179, 1888.

a prism spectroscope. The values thus obtained are thus based directly upon the Ångström system of wave-lengths. Reduction to the Rowland system by multiplication with the factor 1.00016 (according to Rowland), as will be shown below, brings them into very satisfactory agreement with my own.

Since I have given in my former paper on chromium and titanium all necessary information regarding the methods of making and measuring the spectrum photographs as well as of determining the wave-lengths, I may at once go on to the question of the elimination of foreign lines. I have already described on previous occasions the process used for this purpose, and called attention to the difficulties which up to the present time have stood in the way of obtaining results satisfactory in this particular. This is particularly true in the case of comparisons with iron, on account of the great number of lines, especially because the true spectrum of this metal, in spite of the important investigations of Kayser and Runge, cannot by any means be regarded as known. In fact, I have found the same thing to be true in connection with my measures of the spectra of chromium and titanium, viz., that the iron spectrum of Kayser and Runge is to a large extent contaminated with foreign lines, a large part of which might have been identified and removed with the greatest ease. For example, there are present numerous lines of chromium, titanium, cobalt and nickel, and, as will be shown below, all the principal lines of manganese, almost without exception, have been found Even the two aluminium lines at λ 3961.68 and λ 3944.16, which are always present in the electric arc between carbon poles, are classed as iron lines. Similar results, although probably in lesser number, will without doubt be found from a comparison with other metals. This circumstance has led me to make direct comparisons with my own photographs of the iron spectrum in the hope of effecting as reliable as possible an elimination of the iron lines from my spectra. So far as can be seen at present the number of doubtful cases still remaining is smaller than might have been expected at the outset.

COMPARISON OF THE COBALT SPECTRUM WITH PREVIOUSLY KNOWN SPECTRA OF OTHER METALS.

COBALT AND IRON.

The greater part of the iron lines found in my photographs of the cobalt spectrum were identified and removed in the first examination with the aid of simultaneous comparisons with photographs of the iron spectrum. Corresponding with the greater richness in lines of Kayser and Runge's iron spectrum, whether it be that these lines really belong to iron or, as is certainly the case in a great number of instances, to impurities, it is possible here as with chromium and titanium to detect a large number of close coincidences by comparison of our lists, the reality of which can be determined only by means of careful investigations on plates containing both spectra especially made for each individual case. In the following table are given these close coincidences together with the results of the special investigations.

Co λ	Co i	Fe λ	Fe i	Remarks
3474.16	4	74.20	1	Fe missing.
76.16	1.2	76.23	1	Fe lines so weak that coincidence cannot be determined.
76.50	1.2	76.45	1	
78.02	2	77.99	2	
78.70	2	78.75	2	
85.50	3.4	85.48	3	Coincident.
89.55	4	89.55	1	Fe missing.
3502.40	4.5	02.41	1	Fe missing.
05.28	1.2	05.21	2	Divided; λ Co > λ Fe.
06.43	4	06.45	1	Fe missing.
09.97	3.4	10.00	2	Divided; λ Co < λ Fe.
10.52	3.4	10.58	3	Divided; λ Co < λ Fe.
12.77	3.4	12.84	1	Fe missing.
20.20	3	20.20	1	Fe missing.
23.00	2	23.03	1	Divided; λ Co < λ Fe.
25.97	1.2	26.03	1	Fe missing.
29.92	4.5	29.96	3	Divided; λ Co < λ Fe.
53.28	1.2	53.35	1	Fe missing.
64.25	2	64.28	1	Fe missing.
75.48	3.4	75.55	3	Divided; λ Co < λ Fe.
82.00	2	82.00	1	Divided; λ Co > λ Fe.
84.92	2	84.84	3	Divided; λ Co > λ Fe.
85.92	1.2	85.90	3	Divided; λ Co > λ Fe.
87.30	5	87.40	1	Divided.
99.27	2	99.36	1	Divided; λ Co < λ Fe.
3604.61	2	04.60	1	Coincident.
15.55	2	15.47	1	Fe line doubtful.
24.47	2	24.52	1	Coincident.
27.95	3.4	27.97	1	Fe missing.
34.85	2.3	34.86	1	Coincident. Fe line stronger than given by K. and R
36.88	2	36.79	1	Divided; λ Co > λ Fe.
37.48	1.2	37.45	1	Divided; λ Co > λ Fe.
45.36	2	45.28	1	Divided; λ Co > λ Fe.
45.60	1.2	45.69	1	Divided; λ Co < λ Fe.
49.47	3	49.50	1	Coincident. Fe line stronger than given by K. and R.
58.05	1.2	58.13	1	A weak Fe line apparently coincident. Perhaps identical with 58.13?
70.20	1.2	70.26	3	Divided; λ Co < λ Fe.
83.18	3.4	83.24	1	Coincident. Fe line stronger than given by K. and R.
86.63	1.2	86.71	1	Fe missing.
90.87	2	90.92	2	
93.27	2.3	93.22	1	Divided; λ Co > λ Fe.
3707.61	2	07.66	1	Fe missing.
30.61	2.3	30.59	3	Divided; λ Co > λ Fe.
32.53	3	32.60	4	Coincident. Should not Fe be 32.50?
40.32	1.2	40.28	1	Divided; λ Co > λ Fe.
77.65	2	77.62	2	Divided; λ Co > λ Fe.
3805.90	1.2	05.88	1	Fe trace.
16.58	2.3	16.54	3	Divided. Fe line lies between Co 16.58 and 16.46.
45.60	4.5	45.64	1	Fe trace. Belongs to Co.
50.25	1.2	50.17	5	Divided.

Co λ	Co i	Fe λ	Fe i	Remarks
3878.90	2	78.88	5	Coincident.
93.44	1.2	93.53	3	Divided.
94.21	5	94.15	2	Divided; λ Co > λ Fe.
3925.32	2	25.37	1	Divided; λ Co < λ Fe.
41.01	2.3	41.04	4	Coincident.
74.86	3	74.87	1	Coincident. Belongs to Co.
75.47	1.2	75.39	1	Divided; λ Fe < λ Co.
95.44	4.5	95.40	1	Co.
4011.07	1	11.11	1	Coincident?
23.53	1.2	23.57	1	Fe missing.
30.90	3.4	30.90	4	Coincident. All belong to Mn.
33.27	3.4	33.22	4	
34.62	3	34.65	4	
40.75	1.2	40.80	3	Divided; λ Co < λ Fe.
49.42	1.2	49.46	1	Possibly divided; λ Co < λ Fe.
58.34	2.3	58.36	3	Divided; λ Co < λ Fe.
76.72	2	76.78	5	Divided; λ Co < λ Fe.
79.39	1.2	79.38	2	Belongs to Mn.
79.58	1.2	79.56	2	Belongs to Mn.
83.10	1.2	83.09	3	Belongs to Mn.
83.76	1.2	83.76	3	Belongs to Mn.
96.08	2	96.12	5	Divided; λ Fe > λ Co.
4121.47	4.5	21.56	1	Fe missing.
62.33	2.3	62.25	1	Fe missing.
71.02	2	71.05	5	Coincident? Possibly λ Co < λ Fe.
98.56	1.2	98.48	1	Divided; λ Fe > λ Co.
4220.43	1.2	20.50	3	Divided; λ Fe > λ Co.
35.46	1.2	35.46	2	Coincident. Fe line very weak. Belongs to Mn.
48.36	1.2	48.41	3	Divided; λ Fe > λ Co.
81.23	1	81.30	1	Coincident. Intensity Co line variable. Belongs to Mn.
92.40	2	92.42	2	Divided; λ Fe > λ Co.
98.15	1.2	98.22	3	Divided; λ Fe > λ Co.
4301.22	1.2	01.22	1	Fe missing.
03.37	2.3	03.31	1	Fe doubtful.
09.55	2	09.56	3	Divided; λ Fe < λ Co.
51.69	1	51.73	3	Co missing. Belongs to Fe.
57.05	2	57.00	1	Divided; λ Fe < λ Co.
60.98	1.2	60.97	1	Coincident.
73.77	3	73.73	2	Divided; λ Co > λ Fe.
75.09	2.3	75.12	1	Fe missing.
79.37	1.2	79.42	2	Fe missing.
88.02	2	88.07	3	Co v. Fe weak. Coincident?
88.53	1	88.63	1	Co missing. Fe line considerably stronger than given by K. and R.
91.08	1	91.15	3	Divided; λ Fe > λ Co.
91.70	3	91.74	1	Fe missing.
92.02	2.3	92.01	1	
4416.63	1.2	16.62	1	
21.48	2.3	21.43	1	Fe missing.
31.55	1	31.49	1	Coincident?

Co λ	Co i	Fe λ	Fe i	Remarks
4433.38	1	33.38	3	Co missing. Belongs to Fe.
45.21	2	45.21	1	Fe missing.
62.16	1.2	62.17	3	Co missing. Belongs to Mn.
65.95	1.2	66.02	1	Coincident?
71.96	2	72.00	1	Coincident.
77.36	1.2	77.43	1	Fe missing.
81.76	1	81.78	1	Divided; λ Fe > λ Co.
90.24	1.2	90.25	3	Coincident. Belongs to Mn.
92.85	1	92.90	1	Fe hardly trace. Coincident? Co line perhaps a ghost.
4502.38	1.2	02.37	1	Co weak. Coincident. Belongs to Mn.
24.88	1.2	24.97	2	Fe missing.
25.97	1.2	26.05	1	Divided; λ Fe > λ Co.
26.70	1.2	26.72	3	Divided; λ Fe < λ Co.
28.12	2.3	28.05	1	Divided; λ Fe < λ Co.
34.18	4	34.19	1	Fe missing.
46.14	2.3	46.19	1	Fe missing.
64.98	1.2	64.93	2	Divided; λ Fe < λ Co.
81.76	5	81.72	3	Divided; λ Fe < λ Co.
4629.47	4.5	29.50	1	Fe missing.
34.94	1	34.98	1	Fe missing.
51.28	1.2	51.33	3	Fe missing.
80.62	1.2	80.55	1	Divided; λ Fe < λ Co.
98.60	3	98.56	1	Fe missing.
4709.26	1	09.24	3	
09.88	1.2	09.89	1	Coincident. Belongs to Mn.
39.28	1.2	39.32	1	Coincident. Belongs to Mn.
49.89	4.5	49.83	1	Fe trace. Probably λ Fe < λ Co.
54.23	3	54.22	3	Coincident. Belongs to Mn.
61.68	1.2	61.72	1	Co missing. Belongs to Mn.
62.54	2.3	62.54	1	Hardly a trace of Co here. Belongs to Mn.
66.03	2	66.04	1	Belongs to Mn.
66.57	2	66.62	2	Co missing on comparison plate. Belongs to Mn.
4840.41	4.5	40.48	1	Fe trace, apparently divided from Co.
55.85	1	55.86	1	Fe missing.
4942.56	1	42.57	1	Fe trace. Coincident?
68.09	1.2	68.03	1	Coincident?
5007.48	1.2	07.56	2	Divided; λ Fe > λ Co.
13.46	1	13.54	1	Fe missing.
22.36	1.2	22.41	3	Divided; λ Fe > λ Co.
5105.73	2	05.72	5	Coincident. Iron line unimportant.
26.37	2.3	26.37	1	Fe missing.
33.65	3	33.70	5	Divided.
42.65	1.2	42.69	2	Divided; λ Fe > λ Co.
53.43	1.2	53.34	3	Fe missing.
5212.87	2.3	12.91	1	Fe missing.
18.42	2	18.34	1.2	Fe trace. Probably λ Fe < λ Co.
22.71	1.2	22.70	1	Fe missing.
57.81	2.3	57.83	1	Fe missing.
66.71	3	66.78	1	Divided; λ Fe > λ Co.
68.72	2.3	68.79	1	Fe missing.

Co λ	Co i	Fe λ	Fe i	Remarks
5316.96	2	16.91	1.2	Fe missing.
41.53	2	41.55	1	
44.79	1.2	44.70	1	
47.68	2	47.68	1	
53.69	3	53.59	3	Divided. Iron line unimportant.
62.96	3	62.96	1.2	Fe missing.
65.05	1	65.08	3	Perhaps divided and λ Fe > λ Co.
77.98	1	77.94	1.2	Fe missing.
83.56	1.2	83.56	6	Coincident. Belongs to Fe.
5407.74	2.3	07.80	1	Fe missing.
57.72	1	57.78	1.2	Fe missing. Belongs to Mn.

The intensities given by Kayser and Runge for the iron lines are given in the table, reduced as accurately as possible to my scale. It will be seen that of the lines which are here designated as pairs, about one third are in reality separated from each other by a small but clearly recognizable distance. A second third includes those cases in which, on my photographs of the iron spectrum, the respective lines are missing, so that no conclusion can be reached with regard to coincidence or non-coincidence. I consider myself not very far wrong in designating the greater part of them as impurities in Kayser and Runge's iron spectrum, due, in cases of exact coincidence, to cobalt, in others to some other metal. While the relative intensities in general bear out this conclusion, failures to do so on my plates may be due to a greater purity of the iron used by me or to the use of a weaker current. In addition, a number of the principal lines of manganese are found in both spectra as impurities. These manganese lines form only a part of the lines of this metal present in Kayser and Runge's iron spectrum, since a not inconsiderable number had already been stricken from my list of the cobalt lines in the first comparison with iron. These lines will appear again below in the comparison of cobalt with manganese.

Of the remaining pairs of lines, the members of which it has not been found possible to separate, the following appear to be common to both metals:

λ	i Co	Fe
3485.50	3.4	3
3732.53	3	4
3941.01	2.3	4

while the following lines due to iron should be removed from the cobalt spectrum:

λ	i Co	Fe
3878.90	2	5
4351.69	1	3
4433.38	1	3
5383.56	1.2	6

The following lines remain doubtful:

λ	i Co	Fe	λ	i Co	Fe	λ	i Co	Fe
4431.55	1	1	3690.87	2	2	3476.16	1.2	1
71.96	2	1	3805.90	1.2	1	76.50	1.2	1
4942.56	1	1	4011.07	1	1	78.02	2	2
68.09	1.2	1	4360.98	1.2	1	78.70	2	2
5105.73	2	?	88.02	2	3	3604.61	2	1
5365.05	1	3	88.53	1	1	24.47	2	1

Of these lines the first, in case the coincidence can be regarded as exact, is to be stricken from the cobalt spectrum as an iron line. The same is true also of the second line in case the intensity given by Kayser and Runge is correct. I have for the present retained the line, because on my photographs of the iron spectrum it has only a very small intensity.

COBALT AND TITANIUM.

In a careful examination of the comparisons made of these spectra I have found the following lines, which with some probability may be ascribed to both metals:

λ	i Co	Ti
4534.18	4	2.3
4629.47	4.5	2.3
4778.42	2.3	2.3
4928.48	3	2.3
5369.78	3	2.3

while the following lines still seem to be doubtful:

λ	i Co	Ti
3609.46	1.2	1.2
13.90	1.2	2
3890.16	1.2	1.2
98.64	2	2

COBALT AND NICKEL.

As might have been expected, the number of lines having the same position in these two spectra is very great. A careful examination of the plates showing both spectra has given the results contained in the following table:

Co λ	Co i	Ni λ	Ni i	Due to	Remarks
3472.70	2.3	72.68	3.4	Ni	Intensity of the Co line variable.
74.16	4	74.21	1	Co	Also Mn.
76.16	1.2	76.19	1.2		Probably foreign lines, given also by iron.
78.02	2	78.04	1		
89.55	4	89.59	1	Co	
93.11	2.3	93.10	4.5	Ni	
95.81	3.4	95.84	1	Co	
3500.99	2.3	01.00	3	Ni	Intensity of Co line variable.
02.40	4.5	02.44	1.2	Co	
02.75	3	02.76	2	Co, Ni ?	Coincident. Intensities nearly the same.
06.43	4	06.47	1.2	Co	
10.52	3.4	10.47	4		Divided, λ Ni < λ Co.
12.77	3.4	12.78	1	Co	
15.20	3	15.17	4.5	Ni	
18.48	3.4	18.47	1	Co	
19.90	2	19.90	3	Ni	
23.57	3	23.57	2	Co	
24.66	3	24.65	5	Ni	
26.96	4.5	27.00	1	Co	
28.10	1.2	28.13	2.3	Ni	
29.17	3	29.17	1	Co	
29.92	4.5	29.93	1.2	Co	
30.52	1.2	30.51	2		Belongs to Ti.
33.49	3.4	33.52	1	Co	
48.32	1.2	48.34	2.3	Ni	
66.50	3	66.50	4.5	Ni	
69.48	5	69.51	1.2	Co	
71.98	2	71.99	3.4	Ni	
75.48	3.4	75.52	1.2	Co	
77.36	1.2	77.37	1	Co, Ni ?	
87.30	5	87.32	1.2	Co	
88.06	1	88.03	2.3	Ni	
95.00	3.4	95.00	1	Co	
97.83	2	97.84	3.4	Ni	
99.27	2	99.27	2	Co, Ni	
3602.43	1.2	02.41	2.3	Ni	
09.46	1.2	09.44	2.3	Ni	Also in Ti, but should probably be stricken from it.
10.62	2	10.60	4	Ni	
12.90	2	12.86	3.4	Ni	
13.90	1.2	13.90	1.2		Impurity line; also in Ti.
19.54	4	19.52	5	Co, Ni	
24.88	1.2	24.87	3	Ni	
27.95	3.4	27.93	1	Co	
64.25	1.2	64.24	3	Ni	
69.42	1	69.38	2	Ni	
70.58	1.2	70.57	2.3	Ni	
74.30	1.2	74.28	3.4	Ni	
88.56	1.2	88.58	2.3	Ni	
3704.17	3	04.17	1	Co	
36.96	1.2	36.94	3.4	Ni	
39.38	1	39.36	2.3	Ni	

Co λ	Co i	Ni λ	Ni i	Due to	Remarks
3755.59	2.3	55.58	1	Co	
75.70	2	75.71	4.5	Ni	
83.65	2.3	83.67	4	Ni	
3807.26	2	07.30	4	Ni	
31.83	1.2	31.82	3	Ni	
32.02	1.2	32.02	2	Ni ?	
42.20	3.4	42.18	1.2	Co	
45.60	4.5	45.58	2.3	Co	
58.42	2.3	58.40	4.5	Ni	
61.30	3	61.28	2	Co	
73.26	4.5	73.25	2.3	Co	
74.11	3.4	74.08	2	Co	
76.99	3	76.96	1.2	Co	
82.04	3.4	82.02	2	Co	
84.76	2.3	84.75	1.2	Co	
85.40	2	85.45	1	Co	
94.21	5	94.20	2.3	Co	
95.12	3.4	95.10	2	Co	
3906.42	3	06.45	1	Co	
10.08	3.4	10.07	1.2	Co	
36.12	4	36.13	2.3	Co	
41.01	2.3	41.02	1.2	Co	Intensity of the nickel lines variable.
41.87	3	41.88	2	Co	
45.47	3	45.48	1.2	Co	
53.05	3.4	53.07	2	Co	
58.06	3	58.07	1.2	Co	
69.24	2.3	69.29	1.2	Co	
74.86	3	74.83	2		Independent of each other.
78.79	3	78.81	1.2	Co	
79.64	3	79.67	1.2	Co	
87.25	2	87.26	1		
95.44	4.5	95.45	3.4	Co, Ni	
98.03	4	98.07	2.3	Co	
4014.11	2	14.11	1		Common impurity.
21.04	3.4	21.03	1.2	Co	
27.20	3	27.20	1.2	Co	
41.48	2	41.52	2		Coincident. Belongs to Mn.
45.52	4	45.54	2.3	Co	
48.88	1.2	48.87	1		Coincident. Belongs to Mn.
55.69	1.2	55.68	1.2		Coincident. Belongs to Mn.
58.34	2.3	58.36	1	Co	
66.50	3	66.53	2	Co	
68.70	3	68.70	1	Co	
86.47	3.4	86.47	1	Co	
92.55	4	92.55	2	Co	
4110.69	4	10.67	1.2	Co	
18.92	4.5	18.94	2.3	Co	
21.47	4.5	21.48	3	Co, Ni	
50.59	2	50.55	1.2		Divided. λ Co > λ Ni.
4252.46	3	52.46	1	Co	
54.49	2.3	54.50	2		Belongs to Cr.
75.00	2.3	74.94	1		Belongs to Cr.

Co λ	Co i	Ni λ	Ni i	Due to	Remarks
4289.90	2.3	89.90	1		Belongs to Cr.
4331.78	1	31.78	3	Ni	
4401.71	2	01.70	4.5	Ni	
51.77	1.2	51.73	1.2		Belongs to Mn.
59.21	2	59.21	4.5	Ni	
62.60	1.2	62.59	4	Ni	
69.72	4	69.71	1	Co	
70.61	1.2	70.61	4	Ni	
4531.14	5	31.19	2	Co	
34.18	4	34.21	1	Co	
43.99	3.4	44.00	1	Co	
47.06	1.2	47.15	3		Divided; λ Ni > λ Co.
49.80	4	49.85	1	Co	
65.74	4.5	65.78	1.2	Co	
81.76	5	81.79	1	Co	
92.68	1.2	92.69	3.4	Ni	
4600.55	1	00.51	3	Ni	
05.15	2	05.15	4	Ni	
29.47	4.5	29.50	1	Co	
48.83	2	48.82	3	Ni	
68.04	1.2	67.96	2		Divided; λ Ni < λ Co.
86.38	1	86.39	2.3	Ni	
98.60	3	98.58	1.2	Co	
4701.70	1	01.72	2	Ni	
14.58	2.3	14.59	4.5	Ni	
15.93	1.2	15.93	3	Ni	
28.14	3	28.06	1		Divided; λ Ni < λ Co.
54.59	3	54.60	1	Co	
83.60	3	83.53	1		Belongs to Mn. Intensity in Co spectrum too great.
86.73	2	86.66	3	Ni	
4807.10	1	07.17	2	Ni	
13.68	4.5	13.64	1	Co	
16.12	2	16.05	1	Co	
23.70	3	23.67	1		Belongs to Mn. Intensity in Co spectrum too great.
29.19	1	29.18	3	Ni	
31.31	1	31.30	2.3	Ni	
43.60	2.3	43.66	1	Co	
55.59	1	55.57	3	Ni	
66.45	1.2	66.42	3.4	Ni	
73.65	1	73.60	3	Ni	
87.19	2	87.16	1.2		Coincident? Perhaps λ Ni < λ Co.
4918.54	1	18.53	2.3	Ni	
36.01	1	36.02	2	Ni	
53.37	2	53.34	1.2		Coincident.
84.32	1.2	84.30	3.4	Ni	
5017.72	1.2	17.75	3.4	Ni	
35.56	1.2	35.55	5	Ni	
80.70	1.2	80.70	5	Ni	
81.31	1.2	81.30	5	Ni	
5115.56	1	15.55	4	Ni	
37.28	1	37.23	4	Ni	
5453.60	1	53.56	1		Probably divided, λ Co > λ Ni.
83.56	4	83.63	1	Co	Possibly λ Co < λ Ni.

From the fifth column, which gives the origin of the lines as determined from the relative intensities, it is evident that in this particular there is still uncertainty in only the few following cases:

λ	i	
	Co	Ni
3577.36	1.2	1
99.27	2	2
3832.02	1.2	2
3987.26	2	1
4014.11	2	1
4887.19	2	1.2
4953.37	2	1.2
5433.60	1	1

The following lines may be regarded as belonging to both metals:

λ	i	
	Co	Ni
3502.75	2.3	2
3619.54	4	5
3995.44	4.5	3.4
4121.47	4.5	3

Finally, if we compare in the above lists the number of nickel lines observed in cobalt with the number of cobalt lines present in nickel, we find the numbers 58 and 67 respectively. In view of the considerably greater number of lines in the cobalt spectrum, it seems to follow that the sample of nickel used was less contaminated with cobalt than was the sample of cobalt with nickel.

COBALT AND MANGANESE.

In order to eliminate from my photographs as many as possible of the manganese lines present I investigated the spectrum of this metal simultaneously with that of cobalt. Since "Braunstein" proved itself to be poorly adapted for this purpose, I obtained from Baron Nordenskiöld some "Manganosit," a mineral which contains about 98 per cent. of manganese together with only a small portion of iron, calcium, and magnesium. When placed in the electric arc this gives a brilliant and long-enduring man-

ganese spectrum. The following table contains the manganese lines found on my photographs of cobalt:

Co λ	Co i	Mn λ	Mn i	Due to	Remarks	Fe according to K. & K.
3474.16	4	74.20	2.3	Co	Intensity of the Mn line variable.	74.20
3599.27	2	99.30	1	Co		
3608.50	1.2	08.62	3		Divided.	
15.55	2	15.53	1	Co		
84.62	2.3	84.70	1	Co		
3774.72	2	74.81	1		Divided, λ Co < λ Mn.	
3845.60	4.5	45.58	1.2	Co		45.64
60.56	2	60.59	1		Coincident. Both lines weak. Common impurity?	
73.26	4.5	73.23	1.2	Co		
74.11	3.4	74.08	1.2	Co		
94.21	5	94.21	1.2	Co		94.15
3953.05	3.4	53.00	2		Divided, λ Co > λ Mn.	
91.68	2	91.75	1	Co		
95.44	4.5	95.46	1	Co		95.40
4030.90	3.4	30.90	10	Mn		30.90
33.21	3.4	33.20	10	Mn		33.22
34.62	3	34.60	10	Mn		34.65
41.48	2	41.49	5	Mn		41.50
48.88	1.2	48.88	4	Mn		48.88
55.69	1.2	55.68	4.5	Mn		55.69
61.90	1.2	61.88	3	Mn		
79.39	1.2	79.35	4.5	Mn		79.38
79.58	1.2	79.56	4.5	Mn		79.56
83.10	1.2	83.09	4.5	Mn		83.09
83.76	1.2	83.75	4.5	Mn		83.76
92.55	4	92.55	1.2	Co		92.49
4122.42	2	22.53	1.2	Co	Traces in Mn. Belongs to Co.	
4235.30	1.2	35.28	3	Mn		
35.46	1.2	35.45	3	Mn		35.47
57.80	1.2	57.80	3	Mn		57.86
66.04	1.2	66.08	3	Mn		66.15
81.23	1	81.27	3	Mn		81.30
4375.09	2.3	75.10	2		Coincident.	75.12
4451.77	1.2	51.75	3.4	Mn		51.77
57.24	1	57.22	3	Mn		57.24
57.74	1.2	57.71	3	Mn		57.74
58.48	2	58.43	3.4	Mn		58.41
61.25	1	61.25	3.4	Mn		
62.16	1.2	62.17	4	Mn		62.17
90.24	1.2	90.28	3.4	Mn	Co line weak.	90.25
99.07	1	99.06	3.4	Mn	Co line missing.	99.09
4502.38	1.2	02.38	3.4	Mn	Co line missing.	02.37
4709.88	1.2	09.87	3.4	Mn	Co line weak.	09.89
27.55	1.2	27.63	3.4	Mn	Co line missing.	27.62
39.28	1.2	39.27	3	Mn	Co line missing on comparison plate.	39.32
54.23	3	54.23	5	Mn		54.22
61.68	1.2	61.68	3.4	Mn		61.72
62.54	2	62.54	4	Mn		62.54
66.03	2	66.02	3.4	Mn		66.04
66.57	2	66.58	3.4	Mn		66.62

Co λ	Co i	Mn λ	Mn i	Due to	Remarks	Fe according to K. & R.
83.60	3	83.60	5	Mn		83.62
4823.68	3	23.71	5	Mn	Intensity of the Co line variable.	23.69
62.29	1.2	62.28	2.3		Divided, λ Co > λ Mn.	
5149.32	1.2	49.40	1.2		Coincident.	
5413.97	1.2	13.94	2.3	Mn		
57.72	1	57.71	2	Mn		
5517.00	1	17.05	3.4	Mn	Missing in Co.	

As appears from the fifth and sixth columns, which contain the result of an examination of the photographs of both spectra, the greater part of these lines observed in cobalt are undoubtedly due to the presence of manganese as an impurity. The contrary is true only in a few cases in the ultra-violet. The following are the only doubtful pairs, the origin of which has not been determined up to the present time:

λ	i Co	i Mn
3860.56	2	1
4375.09	2.3	2
5149.32	1.2	1.2

I have already called attention to the fact that the iron spectrum of Kayser and Runge contains many lines due to foreign metals, and that among others the principal lines of manganese are almost without exception ascribed to iron. A glance at the last column of the above table is sufficient to prove this. I regard it as not improbable that a searching investigation of manganese, which is to be made later, will still further increase this list. It is undoubtedly true—and I am the first to acknowledge it—that the formation of the spectrum of any substance, absolutely free from all foreign lines, is a task, the solution of which appears at present unattainable, and perhaps will always remain so. But on the other hand some weight cannot be denied to the opinion that Kayser and Runge's representation of the iron spectrum will possess an importance corresponding with the

remarkable accuracy of the measures only when there have been removed from it at least those foreign lines which, like those mentioned above, are immediately obvious. It will be found that such an approximate purification of the spectrum will give no special difficulty.

COBALT AND CHROMIUM.

From repeated investigations of the photographs showing both these spectra, I have found the following cases, in which the origin of the lines is doubtful or may perhaps be ascribed to a third metal:

λ	i	
	Co	Cr
3552.85	2	2
3978.80	1.2	2
4027.21	1.2	2
4564.35	2	2
4697.19	1.2	2
5370.60	1	1.2

The following lines, which either exactly coincide or are only doubtfully separated on the photographs showing both spectra, must for the present be ascribed to both metals:

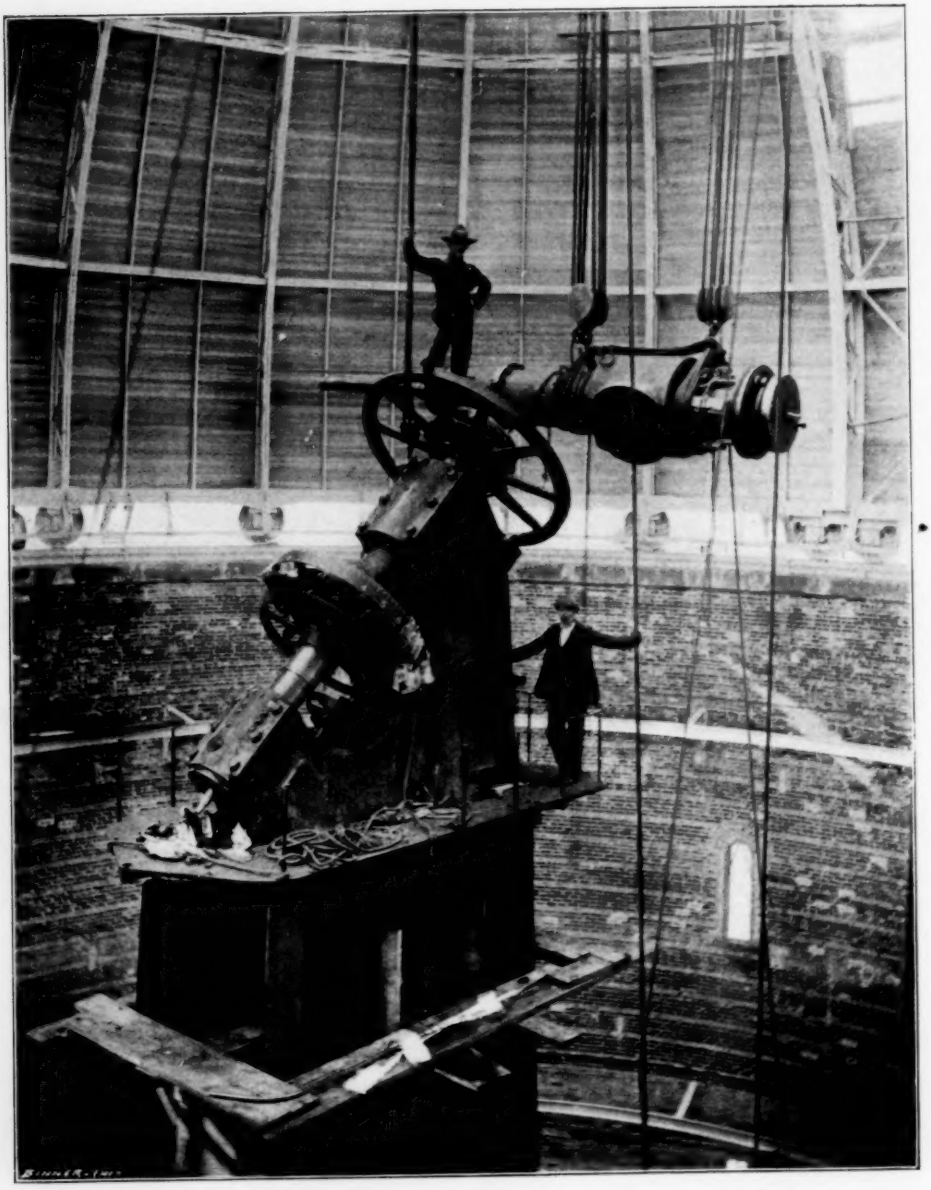
λ	i	
	Co	Cr
3575.06	3	2
3641.95	2.3	3
3894.21	5	3
3969.25	2.3	2
91.82	2	2.3
4546.14	2.3	4
4698.60	3	3

Of these lines the third, fourth, and last coincide exactly in both spectra, while for the remainder there is probably an extremely small difference in position.[1]

[1] In my catalogue of the chromium spectrum the two lines λ 4754.10 and λ 4543.99 are to be stricken out, as they are probably due to cobalt.

[*To be continued.*]

PLATE XII.



ERECTING THE DECLINATION AXIS OF THE YERKES TELESCOPE.

Minor Contributions and Notes.

EYE-ESTIMATES OF STELLAR MAGNITUDE.

In the article by Mr. Roberts entitled "Certain Considerations concerning the Accuracy of Eye-Estimates of Magnitude by the Method of Sequences" (Astrophysical Journal **4**, 184), my views regarding visual observations of the light of the stars are so entirely misinterpreted that a contradiction seems necessary. The statement of Mr. Roberts would be nearly correct if exactly reversed, and if he should say that I do *not* consider "that determinations of variation by Argelander's method are usually inaccurate, generally uncertain, and always insufficient for important lines of investigation." The best evidence of my appreciation of Argelander's method is that for the last ten years we have used it here continuously, and several of our observers now use it every clear night in visual observations. A large part of our photographic magnitudes are also determined by this method. My only criticisms are three which I had supposed were universally admitted. First, that visual estimates cannot give the true ratio of the light of one star to that of another without the aid of some form of photometer. The same objection, of course, applies to all estimates as compared with measures, as in the case of distances, weights, or times. This objection, in the present case, is partly or wholly overcome by the use of photometric magnitudes of the comparison stars in reducing the observations. Second, that in repeated observations, that is, when one observation is made immediately after another, an estimate will not be independent if, as would usually happen, the observer recollected his previous estimate. Mr. Roberts avoids this difficulty by making his estimates at intervals of twenty minutes or half an hour. When the star varies slowly we use here still longer intervals between our estimates, while with a photometer several independent measures may be made in a minute. Third, that the subjective errors, such as those due to the position of the stars and the proximity of bright stars, are large. I am open to conviction as to whether they are completely eliminated by the methods in use here and elsewhere. I had supposed, perhaps erroneously, that they rendered it difficult to determine the character

of small variations. See also an article entitled "Photometric Light Curves of U Cephei and S Antliae," sent to the *Astronomische Nachrichten* August 7, 1896.

On the other hand I fully appreciate the value of the excellent observations described by Mr. Roberts and regret that his article should be marred by matter of a controversial nature.

I shall continue to urge upon astronomers the importance of making observations by the method of Argelander, especially in the case of stars too faint to be within the reach of small telescopes.

EDWARD C. PICKERING.

HARVARD COLLEGE OBSERVATORY,
October 19, 1896.

ON THE MODE OF PRINTING TABLES OF WAVE-LENGTHS.

IN an article recently published in the ASTROPHYSICAL JOURNAL Professor Kayser stated that in his opinion the decision of the Editorial Board to print tables of wave-lengths with the shorter wave-lengths at the top was an ill-advised one.

During Professor Kayser's recent visit to Chicago the opportunity was offered for discussing this question, and as a result of this discussion he was requested to prepare a statement giving his views on the matter. A translation of this statement follows:

"The Editors of the ASTROPHYSICAL JOURNAL having decided to publish tables of wave-lengths beginning always with the shorter waves, I take the liberty of offering you my reasons for thinking that this is *not* perhaps the most advisable plan.

"In general it might appear to be a matter of indifference in which direction the tables run: but I think the following considerations should have weight:

"(1) *Historical development.*—Fraunhofer began his tables with the long wave-lengths, as is shown by his drawing of the solar lines between A and H.

"Ångström, Cornu, and most spectroscopists have followed his example.

"(2) One would naturally wish the tables so arranged that any additions to our present knowledge of spectra might be easily incorporated. This extension of knowledge will, of course, occur *both* in the direction of the ultra-violet and the infra-red. However, the experi-

mental fact is that there are exceedingly few lines in the infra-red; and in the case of most elements none at all. While, on the other hand, the work of Schumann has shown that the ultra-violet is a region probably crowded with yet undiscovered lines.

"But the relative importance of the ultra-violet region is especially manifest when we come to map spectra in terms *not* of wave-lengths, but of wave-numbers.

"And that this is the best adapted of all modes of representation is shown by all the laws hitherto discovered concerning the distribution of lines.

"Let us assume, for the moment, that the infra-red spectrum may be studied between wave-lengths 20000 tenth-meters and 8000 tenth-meters. Say that the spectrum as known at present covers the region between 8000 tenth-meters and 2000 tenth-meters, and that the ultra-violet may yet be investigated between 2000 tenth-meters and 1000 tenth-meters. Now imagine these three regions plotted in terms of frequencies: the ground they cover will be as follows: 50–125, 125–500, 500–1000. That is to say, while the new infra-red region is almost insignificant, the new ultra-violet is larger than all the others put together, including all hitherto known. So that, from this point of view also, it would appear that we should begin with the long wave-lengths.

"(3) The following consideration is to my mind the all-important one, the one which leaves us no choice in the matter:

"For a large number of elements, it has already been shown that their spectra are built up with a definite structure. And time will doubtless show this to be true of *all* elements. These spectra consist of series such that when one substitutes for the variable (in the equation which represents the whole series) the smallest possible whole number, he obtains a line which is at once the longest and strongest in the whole series, the fundamental tone, so to speak. The other lines, the overtones, diminish in intensity toward the violet and finally disappear.

"If, therefore, we consider the regular structure of these spectra—and this structure is becoming daily of more importance—the only logical course would appear to be that in which the long wave-lengths are placed first.

"*All* considerations, indeed, appear to suggest this arrangement: and none, so far as I see, favor the reverse.

"In view of these facts, may it not be wise for the Editorial Board to reconsider its former decision?

"H. KAYSER."

This communication was read at the third annual meeting of the Board of Editors of the ASTROPHYSICAL JOURNAL, held at Princeton University on October 15 and 16, 1896. In the discussion which followed the greater part of the members present seemed to favor Professor Kayser's view. It was pointed out that when the question was considered at the meeting of 1894 the action of the Board was in large part due to the fact that Professor Rowland had previously adopted the plan of placing the red end of the spectrum maps to the right and the short wave-lengths at the top of the table. Various objections had been urged against this plan, one of them involving this very question of the order of lines in series, and the awkwardness of reading from right to left the Greek letters which designate the hydrogen lines. But it was felt that as there are certain series which run in the other direction the decision must be to some extent an arbitrary one. It was considered to be a point of great practical importance that the maps and wave-length tables to be printed in the JOURNAL should correspond with the standard map and tables of the solar spectrum issued by Rowland, and used by all spectroscopists. As the importance of this conclusion has increased rather than diminished during the two years which have elapsed since the question was first discussed, on account of the adoption of this procedure by the members of the Board of Editors and others in various printed works, and especially because of the publication in this JOURNAL of Rowland's extensive wave-length tables, it was felt that no change should be hastily made. It was finally resolved to invite all who are interested in the matter to discuss it in these pages, in order that any further action which may be needed may be based on the opinion of the majority of spectroscopists. Expressions of opinion are therefore solicited for publication.

NOTE ON THE PREPARATION OF PHOSPHORESCENT BARIUM SULPHIDE.

IN some recent experiments with phosphorographic plates, the writer had occasion to use some pure barium sulphide. As this could

not at the time be obtained from any of the Chicago firms dealing in chemicals I decided to prepare it for myself.

Solutions of pure barium sulphide ($Ba\,Cl_2$) and sodium hydrate ($Na(OH)$) were mixed in molecular proportions so as to obtain barium hydrate ($Ba(OH)_2$), and sodium chloride ($Na\,Cl$). Hydrogen sulphide gas prepared and washed in the usual manner was then passed through the concentrated solution, throwing down the barium sulphide as a flocculent sparingly soluble precipitate, leaving only sodium chloride in solution. The complete reaction is

$$Ba\,Cl_2 + 2\,Na\,(OH) + H_2S = Ba\,S + 2\,Na\,Cl + 2\,H_2O.$$

The precipitate was collected on a filter, sparingly washed with cold water, and thoroughly dried in a steam bath. Although barium sulphide is, as is well known, ordinarily strongly phosphorescent, it showed, when prepared in this way, only the faintest traces of phosphorescence even after exposure to bright sunlight for several hours. Somewhat nonplussed by this discovery, of which I could find no mention in any of the works on chemistry which I consulted, I determined to try some of the same material prepared in the ordinary way (by fusing together barium carbonate and sulphur). This, although not as strongly luminous as the powdered blende (perhaps because of impurities), was fairly satisfactory. It then occurred to me that the phosphorescent property might be due to the action of the high heat employed in the dry process of preparation, and that the precipitated material might similarly be rendered luminous by heating. An experiment with a small fragment of the dried precipitate which was placed in a small porcelain crucible and heated over a gas blowpipe, showed this to be the case.

The power of phosphorescing depended to some degree on the degree of heat applied and the length of the heating.

These experiments are of interest as indicating that barium sulphide may exist in two molecular states, chemically identical but physically different. It will be interesting to determine whether this change is accompanied by corresponding changes in other physical properties as in the case of fluorspar, lepidolite, and some other substances which become phosphorescent when only moderately heated.

As soon as time permits further experiments will be made on this and other interesting questions which have presented themselves.

F. L. O. WADSWORTH.

NOTE ON A COMBINED EQUATORIAL TELESCOPE AND POLAR HELIOSTAT.

SINCE my review of Dr. Stoney's article was written last month (ASTROPHYSICAL JOURNAL, **4**, 238) I have learned through Professor Young that the plan there proposed of combining an equatorial telescope and polar heliostat was used some years ago by Professor Langley at the Allegheny Observatory. While the plan is so simple that I hardly supposed it could be wholly new, I did not at the time of writing know that it had actually been used. I am very glad to find that the plan has the endorsement of practical use by such a well-known astrophysicist as Professor Langley. F. L. O. WADSWORTH.

A CORRECTION.

I AM very sorry to note that . . . . one error occurs in my article on the "Solar Rotation."[1] Equation (9*a*) page 103, which gives

$$P = cT(1+\log\rho).$$

is wrong, and consequently also equation (10). This does not at all affect the validity of that which follows, since these equations are not used. Equation (10) ought to be

$$4\pi\rho + c\Delta T + cT\Delta\log\rho + \frac{c}{\rho}\left(\frac{\delta T}{\delta x}\cdot\frac{\delta\rho}{\delta x} + \frac{\delta T}{\delta y}\cdot\frac{\delta\rho}{\delta y} + \frac{\delta T}{\delta z}\cdot\frac{\delta\rho}{\delta z}\right)$$

$$= 2\omega^2 + r\frac{d\omega^2}{dr}$$

E. J. WILCZYNSKI.

BERLIN, September 28, 1896.

CHANGE OF ADDRESS.

I WISH to call attention to the fact that the instruments and apparatus of the Kenwood Observatory have been permanently removed to the Yerkes Observatory. Hereafter all communications intended for the ASTROPHYSICAL JOURNAL, the Kenwood Observatory, the Yerkes Observatory, for Professor E. E. Barnard, Professor F. L. O. Wadsworth, or for the writer, should be addressed to the *Yerkes Observatory, Williams Bay, Wisconsin, U. S. A.* GEORGE E. HALE.

[1] *Ap. J.*, **4**, 101, August 1896.

Recent Publications.

A LIST of the titles of recent publications on astrophysical and allied subjects will be printed in each number of the ASTROPHYSICAL JOURNAL. In order that these bibliographies may be as complete as possible, authors are requested to send copies of their papers to both Editors. For convenience of reference, the titles are classified in thirteen sections.

1. THE SUN.

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CAJORI, F. Search for solar X-rays on Pike's Peak. Am. Jour. Sci. (4) **2**, 289–290, 1896.

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7. NEBULÆ AND THEIR SPECTRA.

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8. TERRESTRIAL PHYSICS.

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